CHENNAI METROPOLITAN WATER SUPPLY & SEWERAGE BOARD

TENDER NO:
CMWSSB/CNT/WSS/ICB/JICA/DESAL/CP01/______/2020-21

LOAN AGREEMENT NO. ID-P267

JICA FUNDED PROJECT

REQUEST FOR PROPOSAL DOCUMENT

FOR

PROJECT FOR CONSTRUCTION OF CHENNAI SEAWATER DESALINATION PLANT (I)

PART-II

(EMPLOYER'S REQUIREMENTS)

PROCUREMENT OF DESIGN/ENGINEERING, CONSTRUCTION, COMMISSIONING OF 400 MLD SEAWATER REVERSE OSMOSIS (SWRO) DESALINATION PLANT AT PERUR, CHENNAI WITH 20 YEARS OF OPERATION AND MAINTENANCE (DBO BASIS)

INTERNATIONAL COMPETITIVE BIDDING

PROJECT MANAGEMENT CONSULTANTS
SMEC International Pty Ltd.
NJS Engineers India Pvt. Ltd.
Tata Consulting Engineers Ltd.
SMEC India Pvt. Ltd.

SUPERINTENDING ENGINEER (CONTRACTS & MONITORING) CHENNAI METROPOLITAN WATER SUPPLY & SEWERAGE BOARD

Date of Issue of Request of Proposal: xx/xx/xx

PART-II- EMPLOYER'S REQUIREMENTS

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SECTION VI EMPLOYER'S REQUIREMENTS

1. PROJECT REQUIREMENTS

1.1 Background to the Project

The Chennai Metropolitan Area (CMA) is facing chronic water shortage due to the lack of rainfall and the increasing population and growing economy. The surface water from the rivers and reservoirs, as well as the groundwater, has been the major water resources for the CMA. However, the yields from such conventional water resources are not stable because of the frequent droughts.

The supply of potable water in the CMA is not sufficient to meet the water demand in the area. It is revealed that in wide areas of Chennai, the service continuity is only three to four hours a day. As per the estimate of the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB), the estimated water production in 2015 was about 6861 million liters per day (MLD) against the demand of 933 MLD. To secure sufficient water supply for the people and industries, the State Government of Tamil Nadu (GoTN) decided to construct seawater desalination plants (DSPs) as one of the reliable water resources, which would not be subjected to the recurring droughts.

At present, two DSPs, one in Minjur (100 MLD) and another in Nemmali (100 MLD), are already operational in the CMA, but the water demand is not yet satisfied. In order to further augment the water supply, GoTN has awarded a contract for the expansion of the existing Nemmeli DSP by 150 MLD and also has initiated a construction plan for a DSP of 400 MLD capacity at Perur (Chennai Seawater Reverse Osmosis Desalination Plant). Following the state government's direction, the CMWSSB prepared the detailed project reports (DPRs) for the 400 MLD project, and the Government of India (GoI) approved the DPR and proposed the construction of Perur 400 MLD DSP for Japanese Official Development Assistance (ODA) loan. Subsequently, the Japan International Cooperation Agency (JICA) carried out the Preparatory Survey on Chennai Seawater Desalination Plant Project. After prolonged deliberation, an agreement was signed between GoI, GoTN and the loan provider JICA on March 29, 2018 to construct the 400 MLD desalination plant at Perur, Chennai.

Through this tender, Chennai Metropolitan Water Supply and Sewerage Board intends to construct a Seawater Reverse Osmosis (SWRO) based 400 MLD desalination plant at Perur, Chennai, Tamil Nadu, India to augment further the drinking water supply to the city of Chennai. The said installation should have a total product water capacity of 400 MLD.

This project involves the construction of intake and outfall structure along with the required pipelines, construction of pre-treatment processes, SWRO desalination plant, remineralisation plant, GIS-based electrical substation and other allied processes and units to build a complete operating plant within the proposed site premises for the production of 400 MLD potable water of the required drinking water quality. After testing and commissioning works, the Plant shall be operated and maintained for 20 years under Design Build Operate (DBO) basis. The Contractor shall be responsible for all the works related to the construction and 20 years O&M of the Plant as per the provision of the contract.

1.2 Description of the Works

1.2.1 The Works

For the purpose of this Tender, the **Work(s)**, is the construction of 400 MLD Seawater Reverse Osmosis (SWRO) Desalination plant at Perur, Chennai with seawater intake and brine outfall pipelines, sludge treatment facility and all other works at the site followed by 20 years of operation and maintenance (O&M) as per the Part-3, Condition of Contract to produce 400 MLD potable water of the required quality. For the purposes of defining the different activities and obligations under the Contract, the Contract will be comprised of a "**Design-Build (DB) Works**" and an "**O&M Works**". The DB Works mean the design, execution, completion, commissioning, trial run and process proving of the Works for the proposed 400 MLD desalination plant and the remedying of any defects. O&M Works is the Operation and Maintenance of the facilities for the period of 20 years.

1.2.2 Description of the Works

The main purpose of this project is to construct a 400 MLD Seawater Reverse Osmosis (SWRO) Desalination plant at Perur, Chennai in order to operate the Plant automatically without any trouble. The contractors are encouraged to visit the plant site and understand the site location and requirements to construct the Plant. If additional works are needed which have not been mentioned in the tender documents or in Schedule of Costs, then Contractors must identify those additional works separately and include in the offered cost. The Plant will be built in two streams of 200 MLD each. All the process units, storage tanks, chemical buildings shall be kept separate for the two streams with only common intake and outfall system. The major areas of works included but not limited to, the following are:

a) Seawater intake system with Intake head, pipeline, intake well, band screens and pumping station
b) Pre-chlorination - chlorine storage and dosing system
c) Flash mixing and distribution chamber
d) Chemical building and coagulant/flocculant storage and dosing system
e) Flocculation and clarification system with tube settlers
f) Dissolved Air Flotation system
g) Gravity dual media filtration system
h) Reverse osmosis desalination system with all chemical storage and dosing systems
i) Remineralisation system (limestone filters) with CO_2 generation units
j) Post-chlorination - chlorine storage and dosing system
k) pH adjustment with caustic soda
l) Sludge treatment with thickeners and belt press filters
m) Brine outfall system with waste tanks, pipeline and offshore diffusers
n) Service water system and all yard pipes at the site

o) All electrical and instrumentation equipment

p) MCC rooms and substations

q) SCADA system and Control system

r) Buildings and all concrete and metal tanks at the site

s) Mechanical and electrical workshops

The detailed technical specifications of the above works have been provided in the following documents of Section VI, Part-2.

Section VI: Employer's Requirements

A. Technical Specifications

1. Project requirements
2. Site details
3. Process plant details
4. General civil requirements
5. Particular civil requirements
6. Pipelines, pipework and fittings
7. General mechanical requirements
8. General electrical requirements
9. General instrumentation, control and automation requirements
10. Inspection and testing requirements
11. General painting and protection requirements
12. Training and advisory requirements
13. Operation and maintenance
14. Hand over

1.2.3 Scope of the Works

The Scope of Works under Contract shall include the design, supply, construction and installation, commissioning, testing, process proving, documentation and process proving of the 400 MLD seawater desalination plant at Perur, Chennai followed by the operation and maintenance for 20 years on Design Build Operate (DBO) basis. The Works shall be executed as per the Technical Specifications. This part of the specifications should be read in conjunction with other parts of the specifications, drawings and appendices which provide further scopes and details.

The Works include all process, mechanical, electrical, civil, instrumentation and control, and all other allied works required for the construction of the 400 MLD seawater desalination plant with a sludge treatment and waste disposal facilities. The Plant shall be built in two similar process streams - each of 200 MLD capacity and fully separated to each other. The intake pumping system shall be common for both the process streams. The Plant shall be fully automated and complete in all respect to the world-class standard even though the specifications in this bid documents do not cover the complete requirements.

The Contractor shall be fully responsible to ensure that the whole of the Works, including each component, is designed and constructed in a manner so that the System as a whole operates as a fully integrated system which is capable of achieving the required output efficiently and economically, and of including all the Plant, equipment and accessories required for the safe and satisfactory operation of the facilities. To achieve this, the Contractor shall ensure that each individual component performs in a manner which is complementary to that of all other components. Any accessories which are not specifically mentioned in the specifications, but which are usual or necessary for the completion of the Works and successful performance of the System and facilities shall be provided by the successful Bidder within the tendered cost. The Contractor shall, to the maximum extent practical and feasible, endeavour to standardise on the manufacture and supply of Plant and equipment to minimise the operation and maintenance requirements. The Contractor shall ensure that his designs are "maintenance-friendly" and that all items of Plant and equipment are designed and installed in a manner which will facilitate routine and periodic maintenance operations.

Apart from the above, the works to be executed by the bidder shall include but not be limited to the following. The details of the works have been covered in the civil, electrical/Instrumentation and mechanical specifications of Part-2.

a) Elevation of the site land up to CD +6.5m to protect the Plant from strong waves and during Tsunami.

b) Construction of internal roads, including connecting roads to site from existing East Coast Road (ECR) to have separate and independent entries to plant/site.

c) Stormwater drainage within battery limits and extension up to the nearest drain/point of disposal. Stormwater has to be collected on the plant site and to be used for rainwater harvesting.

d) Drinking water & sanitation water system for operation & maintenance personnel, yard lighting and fencing around equipment/ units, etc.

e) Construction of permanent boundary walls and/or fence and internal fencing, entry gates and lighting including any temporary fencing required during construction as per the contract.

f) Solar Street lighting to illuminate the street as per specification in the contract.

g) Ventilation system for all buildings and units, Fire Fighting System, Tools & Tackles for the handling of equipment during maintenance.

h) Commissioning spares

i) The laboratory is complete for efficient operations of the Plant. The list of equipment to be provided is as given in the contract.

j) Site services as required for the construction and commissioning of the RO Plant including start-up and handover

k) Lay-down areas, warehouses, workshops for site construction and prefabrication purposes, vehicles, mobile equipment etc.

l) The Plant shall be constructed with minimal leakages. Leakage if any shall be transferred to the plant intake well. Leakages have to be monitored, counted in m^3/d and be part of the reporting. Maximum % of leakages has to be stated by EPC and to be part of the O&M contract.

m) A minimum of 6 Metro Water Engineers/ personnel will be trained every year on-site for at least two months in every function of the regular O&M personnel." "Necessary staff of the Chennai Metropolitan Water Supply & Sewerage Board (CMWSSB) shall be deployed to the site of the Plant for supervision/participation during construction and operation.

n) The Plant shall be connected to the national Tsunami warning system directly. In case of a Tsunami warning, an alert shall be issued. A programme shall be introduced so that the Instrumentation and Control System (INC) of the Plant shall set the Plant into a safe mode (including backflushing/ cleaning of membranes with desalinated water, closing all interconnected valves to the membranes and shutting down all electrical devices) to minimise the damage to the Plant. The evacuation of the staff shall be planned and executed according to an occupational health and safety system. A yearly mock drill shall be conducted in the presence of CMWSSB officials to secure the operation of the Tsunami Response System. The result of this mock drill shall be reported to CMWSSB. The SCADA system shall give the possibility for remote control of the Plant from CMWSSB's main control room.

o) The Contractor shall comply with requirements specified under Environment (Protection) Act, 1986, and Water (Prevention and Control of Pollution) Act, 1974, Air (Prevention and Control of Pollution) Act, 1981 and Noise Pollution (Regulation and Control) Rules, 2000 and Hazardous Material (Management, Handling and Transboundary Movement) Rules, 2008 as applicable to the project and also with all other applicable current legislation, regulations and specifications, with respect to all measures, operations and administrative steps required for the full protection and safeguarding of the environment.

p) The CMWSSB is responsible for obtaining necessary permits/clearances from the State/Centre Regulatory agencies namely Coastal Regulation Zone (CRZ) Clearance under CRZ Notification 2011, Consent to Establish from Tamil Nadu State Pollution Control Board (TNPCB) and Approval / NOC from the Forest Department for the Wildlife Conservation and Management Plan. Other than the permits/ clearance as specifically mentioned above, the Contractor shall be responsible for obtaining necessary permits/clearances from the State/Centre Regulatory agencies under the applicable laws namely Consent to Operate from TNSCB and others as applicable to the project and comply with all such requirements during the entire period of the contract, i.e. during Construction Stage and Operation Stage.

q) After award of the contract and before the start of work, the Contractor shall review the available Environmental and Social Management Plan (ESMP) for the project available with CMWSSB. The Contractor shall duly update the ESMP to ensure compliance with all applicable legislation and regulations of State / Central Government and also with Sustainability Guidelines of KfW and IFC Performance Standards on Social and

Environmental Sustainability. The ESMP shall incorporate the requirements stipulated in the Project's EIA Report and conditions of approval from State/Centre Regulatory agencies. The ESMP shall also clearly define roles, responsibilities, reporting requirement and budgetary allocations for implementation of mitigation measures. The revised ESMP shall be submitted by the Contractor to CMWSSB for necessary approval before initiating any groundwork.

r) The ESMP updated by the Contractor shall include all required Sub-plans. The Sub-Plans to the ESMP to be prepared by the Contractor shall include but not be limited to:

- *Stakeholder Engagement Plan* which explains interaction with the community, including project information disclosure and emergency response planning relevant for the community. This sub-plan should cover means and methods to inform affected population about construction schedule and expected impacts such as access limitation to properties if any and also spell out the grievance redressal mechanism available to the communities to ensure any concerns brought to the CMWSSB are resolved appropriately and in a timely manner.

- *Waste Management Plan* covering brine discharge / solid disposal and compliance with regulatory standards. The plan shall contain quantities and type of waste as well as type of disposal. It shall cover all waste generated such as brine, pre-treatment sludge, CIP wastewater, solids, R.O. membrane etc. The design of the outfall shall comply with EIA study and waste disposal regulations as per the Ministry of Environment and Forest Government of India, (MOEF) and State Pollution Control Board (SPCB). The quality of return water to be discharged into the sea shall meet TNPCB requirement (tolerance limit for the discharge of trade effluents into Marine Coastal Areas as per Water (Prevention and control of pollution) Act, 1974). The used RO membranes shall be sustainably reused/ recycled/disposed of in compliance with Indian laws and regulations. The way of reusing / recycling /disposal will be reported regularly to CMWSSB. Confirmation of official disposal sites shall be provided as and when identified by the Contractor after getting approval from CMWSSB in concurrence with TNPCB.

- *Turtle Nesting Conservation Plan* for the beach in front of the project premises to address threats to the turtle populations from fishing activities, artificial lightening's from anchoring vessels, oil spills etc. The project activity such as pipeline laying is not likely to affect the Turtle nesting as they will be buried more than 1.0 m from the sea bed surface hence, not expected to interfere with the turtle nesting. Also, the water pipe laying is suggested to be undertaken in the non-breeding season to further reduce the impacts. The conservation plan should enlist certain activities and should allot budget to them. Some of the indicative activities for conservation are: minimising impacts from lightings towards the seaside for Turtle hatchlings and cooperation with local Turtle conservation groups in order to conserve a maximum of Turtle eggs laid near the facility. In this regard CMWSSB will extend support to Forest Department/ WWF – India Personnel / Students Sea Turtle Conservation Network (SSTCN) for the conservation of Olive Ridley Turtles as required.

- *Separate E&S Management Plans for Construction and Operations Stages* shall be prepared to address the impacts associated with construction and operation activities on the environment, the workforce engaged and surrounding communities. These plans shall incorporate the requirements stipulated in the Project's EIA Report, applicable legislation and regulations, conditions of approval from State/Centre Regulatory agencies and also considering best practices and good engineering practices, as applicable.

- *Environmental and Social Monitoring Plan* shall be prepared to ensure that the envisaged purpose of the ESMP is achieved across all stages of the project. Performance indicators will be developed for critical environmental and social conditions. For each of the indicators, the monitoring plan will specify parameters to be monitored, the location of monitoring sites along with frequency and duration of monitoring. The monitoring plan will also specify applicable standards, implementation and supervising responsibilities and reporting requirements.

s) The Contractor shall implement all requirements of the ESMP approved by CMWSSB during the entire period of the contract, i.e. during Construction Stage and Operation Stage of the SWRO based Desalination Plant and associated facilities.

t) Operation and Maintenance of the aforesaid SWRO based Desalination Plant and associated facilities is to be carried out strictly as per the approved ESMP and as directed by the CMWSSB and State/Central Pollution Control Board Norms.

u) The Contractor shall seasonally monitor the environmental quality of the working sites and their surroundings in terms of environmental and social performance indicators as specified in ESMP and submit the monitoring results to CMWSSB. The Contractor shall also be responsible for periodic submission of Monitoring Reports to the Regulatory Agencies in compliance with requirements of the ESMP.

v) All pressure containing equipment and components shall be designed, fabricated, tested, and inspected in accordance with project specification and ASME Section VIII, Div 1. Material certification to BS-EN-10204:2004 shall be supplied for all items.

w) Inspection and Quality Control of all equipment and civil works, Erection, Commissioning, trial run, along with all consumables and manpower, project management and monitoring for timely submission of design documents and drawings and timely execution of the project with a demonstration of performance guarantee parameters including the supply of all measuring instruments and manpower.

x) Training of at least 6 operators/engineers of CMWSSB for the plant Operation and maintenance.

y) The Bidder's proposal shall include details and references of the recorded operational reliability of the key equipment and systems to be provided. The proposal shall include a description of the RO Plant's ability for flexible operations.

z) Industrial workshop with suitable size EOT cranes for maintenance – area up to 2000 sqm

aa) Sewage Treatment Plant of capacity 20 KLD. The sewage shall be treated to the quality approved by the regulatory authority for wastewater reuse.

bb) Garden & Landscaping work shall be done in front of Administrative building and all open areas at the site to the satisfaction of the Engineer.

cc) - Security Cabin – two security cabins each of size 20.0 sq.m floor area for two plant gates shall be designed & constructed in RCC frame structure with 230mm thick brick / concrete block panelling, including sand face plaster & cement-based paint from outside and plain cement plaster from inside. Height of the Security Cabins shall not be less than 3.0 m. Window opening shall be to the extent of 20% of wall surface area with 100% Glazing.

1.2.3.1 *Summary of the Scope of Works*

The Works shall include the:

- Designing, construction, procurement, installation, commissioning and 20 years operation and maintenance of a 400 MLD SWRO desalination plant on Design, Build and Operate (DBO) basis
- Plant process and hydraulic design and construction for two fully separate process streams of capacity 200 MLD each
- Procurement and installation of all mechanical/electrical and instrumentation works
- Design and construction of all civil structures and building works
- All piping works at the site (including intake & outfall pipes off seashore) and all mechanical/electrical/civil general arrangement and section drawings
- Full automation of plant processes
- Design and manufacture, supply, testing at manufacturers' works, storage when required, delivery to site, unloading and site transportation, erection, site testing, painting and finishing of the Plant
- testing, commissioning, process proving and 20 years of operation and maintenance of the SWRO desalination plant
- provision of spare parts, special tools, operation and maintenance manuals and As-Built drawings

1.3 Raw Water

1.3.1 Raw Water Source

The proposed site for 400 MLD Perur SWRO Plant is within 1 km of the site of 100 MLD Nemmeli desalination plant. The records of seawater quality at 100 MLD Nemmeli desalination plant cover data for a period of 5 years which is the only extended continuous data available for the plant design. It is to be noted that the maximum TDS values up to 39,500 mg/l were recorded on a short period during April 2018 to May 2018, over 5 years of data recording. Apart from this short period, all TDS records at 100 MLD Nemmeli plant are below 38,500 mg/l (plant laboratory operated by Wabag).

The variation of TDS over more than 5 years period is presented below in Figure 1.

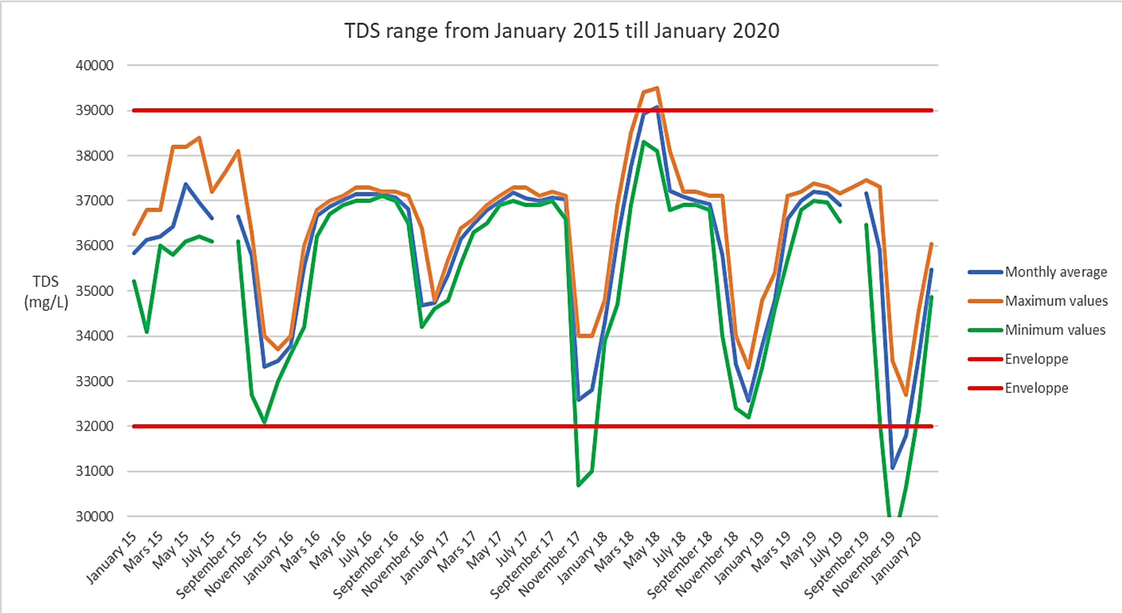

Figure 1: TDS profile over a period of 5 years (Nemmeli Data)

The TDS range is quite extensive due to freshwater impact during the Monsoon period. The decrease of TDS (to 32000 mg/l) in November every year is repetitive, and its intensity depends on the rainfalls. Except for two restricted periods in 2015 and 2018, repeatability of TDS values below 37,500 mg/l are observed during spring and summer before the rainy season.

Considering the above, the range of TDS adopted for the Perur RO design is 32000 mg/L to 39000 mg/l, which is quite reasonable. Higher than 39000 mg/L value may lead to the need for 2nd pass RO system for maintaining product water TDS limit below 450 mg/l and in case of the use of all high-rejection membranes, this value will increase the operating range of the high-pressure pump resulting in an increase of the operating cost.

The variation of TSS in seawater over 5 years period is presented below in Figure 2.

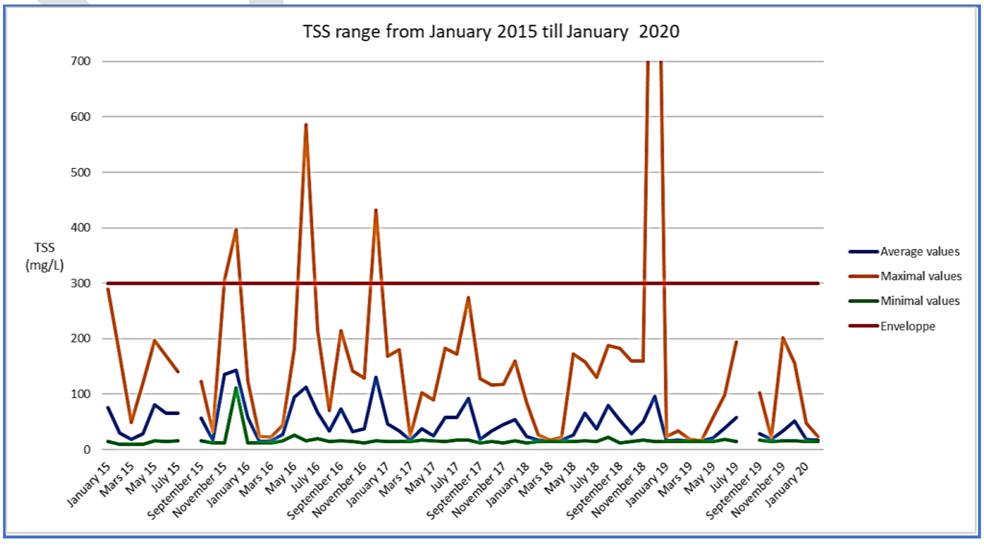

Figure 2: TSS profile over a period of 5 years

A peak of TSS reached 1478 mg/l in December 2018. Usually, such abnormal value (one day) is considered an outlier and discarded. The maximum value of TSS in seawater has been considered at 300 mg/L for the pre-treatment design purpose.

TOC (total organic carbon) is an important parameter to monitor since it is responsible for biofouling on the membrane surface. It is also revealed that the seawater in the site vicinity contains small white particles which are organics in nature and result in membrane fouling and frequent cleaning. Bidders are advised to investigate seawater for the TOC content and design the pre-treatment accordingly to avoid membrane fouling.

The desalination plants at Minjur and Nemmeli have recorded specific event of jellyfish attacks, but regarding HABs (Harmful Algae Blooms or "red tides"), they have no specific records. However, such events have been reported in the local press and research papers.

Table 1 provides the maximum, minimum and mean values of the seawater characteristics at Perur.

Table 1: Raw seawater design parameters

Jan'2015-Jan'2020	Minimum value[1]	Mean value[3]	Maximum value[2]
SWRO parameter envelop			
TDS	32000	36000	39000
pH	8.00	8.13	8.20
Temperature	26.0	28.3	31.5
Boron	3.2	3.53	3.80
Pre-treatment parameter envelop			
Turbidity	1.0	12	150
TSS	10	75	300
Total Organic Carbon [4] (TOC)	3.0	5	8
Hydrocarbon contents [4]			0.10
Algae count (cells per ml) [4]	100	500	30000
Jellyfish attacks	N.A	N.A	Yearly Occurrences

[1] Minimum is the monthly minimum data over Jan 2015 to Feb 2020
[2] Maximum is the monthly maximum data over Jan 2015 to Feb 2020
[3] Mean is the monthly average data over Jan 2015 to Feb 2020
[4] Assumed values, to be confirmed by the bidder

1.3.2 Product Water Quality

The Product water quality requirements at the inlet of clear water reservoir are specified in the

CPHEEO Manual on Water Supply and Treatment guidelines. The product water TDS shall be less than 450 mg/l, Boron < 1 mg/l, turbidity < 0.5 NTU, TSS < 0.5 mg/L and hardness ≥ 80 mg/l as $CaCO_3$ for 95% of the time a day. All other parameters shall meet the CPHEEO drinking water guidelines.

1.4 Design Flow and Capacity

The SWRO desalination plant at Perur shall be able to treat minimum 1040 MLD seawater to produce net 400 MLD product water at the entrance of Clear Water Reservoir (CWR). CWR and pumping station to transfer water to Porur are not in the scope of this contract. A preliminary mass balance of the plant process is attached in

1.5 Mass Balance for the Proposed Plant

The mass balance (water and TSS) calculations for the process of the 400 MLD SWRO desalination plant for the average and maximum flow rates at RO recovery 46% and 42% are presented in the Part-2 Section VI-C Drawings. The preliminary calculations for mass balance for 400 MLD desalination plant for 42% and 46% recovery are presented in Table 2 and Table 3. As there are two process streams of 200 MLD each. The flow to each stream will be half of the flow given below. The Plant will be running most of the time at 46% RO recovery, and the recovery will be reduced to minimum 42% in case of an adverse situation of feed water quality and/or during the possibility of vigorous membrane fouling.

Table 2: Indicative Mass Balance for 400 MLD Desalination Plant at 42% RO Recovery

Process Stage	m^3/day	Wastewater	Factor to Feed Flow
Intake Pumps	1,038,431		100%
Service Water	2,000		0.2%
Utility and Leakage		5,192	0.5%
Lamella + DAF waste		31,053	3.0%
GMF Backwash		40,442	3.9%
Pre-filtered water	961,955		92.6%
Feedwater RO+ERD	961,955		92.6%
Feed to RO	961,905		92.6%
HP pumps	404,000		38.9%
Recir. Pump	557,905		53.7%
Feed to ERD	557,955		53.7%
RO permeate	404,000		38.9%
RO Reject		557,955	53.7%
CIP & Flushing		2,000	0.2%
Total plant waste discharge		636,642	61.3%
Net Plant Product Water	402,000		38.71%
Overall Plant Recovery	38.7%		

Table 3: Indicative Mass Balance for 400 MLD Desalination Plant at 46% RO Recovery

Process Stage	m^3/day	Wastewater	Factor to Feed Flow

Intake Pumps	948,160		100.00%
Service Water	2,000		0.21%
Utility and Leakage		4,741	0.50%
Lamella + DAF waste		28,363	2.99%
GMF Backwash		36,938	3.90%
Pre-filtered water	878,311		92.63%
Feedwater RO+ERD	878,311		92.63%
Feed to RO	878,261		92.63%
HP pumps	404,000		42.61%
Recir. Pump	474,261		50.02%
Feed to ERD	474,311		50.02%
RO permeate	404,000		42.61%
RO Reject		474,311	50.0%
CIP & Flushing		2,000	0.21%
Total plant waste discharge		546,352	57.62%
Net Plant Product Water	402,000		
Overall Plant Recovery	42.4%		

1.6 Design Criteria for the Proposed Plant

The overall design criteria of the Plant are given below in Table 4 below. Bidders shall include these design criteria in their price bid cost for the construction of the 400 MLD SWRO desalination plant and the associated works. In case of any suggestion for a change in the design criteria, bidders may raise this in the pre-bid meeting and get it resolved. Further details of the design may be discussed later with the Contractor during the detailed design of the Plant.

Table 4: Indicative Design Criteria for 400 MLD Desalination Plant at Perur

Process Stage	Design Criteria (2 x 200 MLD)
Product water	• *According to Indian Standard:* ○ *TDS ≤ 450 ppm,* ○ *Chlorides ≤250 ppm* ○ *Turbidity ≤ 0.5* ○ *Boron < 1.0 ppm* ○ *Hardness ≥ 80 mg/l as* $CaCO_3$ ○ *LSI - slightly positive* ○ *pH – 6.5 to 8.5*
RO recovery	• *Nominal RO recovery: 46% (provision for 42%)*
The offshore seawater intake system	• *Submerged open-intake @ min 10 m seabed depth* • *Velocity cap type* • *Horizontal velocity at 0.12m/s* • *Screen bar with 10cm spacing with a fishing net* • *Shock chlorination + air compressed pipes*

Process Stage	Design Criteria (2 x 200 MLD)
Offshore seawater intake pipes	• *2 pipes (buried) of HDPE (2500 mm OD SDR <26)* • *Length TBD after brine diffusion study* • *Same profile/ alignment*
Brine outfall system	• *1 pipe in HDPE OD 2500 mm. SDR 26* • *Total length: TBD after brine diffusion study* • *Brine diffuser: >30 units diam 350mm spaced 6 m.*
Ancillary equipment for the intake system	• *Intake well (4 Chambers)/ 4 sets Band screens (3W+1S)* • *Shock dosing pump* • *The two pipes are designed to be cleaned by a pigging system with a launcher/ receiver installed in the pumping station/ intake.*
Seawater intake pumping station – provides water to two streams of 200 MLD each	• *6 + 2SB units of vertical turbine pump for total flow 43333 m^3/h (1040 MLD); Minimum flow:* 39500 m^3/h *(948 MLD) @ 46% RO recovery* *(half of the flow to each stream)* • *Discharge pressure: >18 m* • *Presence of VFD*
Pre-treatment	• *Composed by chemical and physical processes.* • *Main stages:* o *Coagulation/flocculation* o *Clarification by Lamella Settler* o *Dissolved air flotation* o *Dual media gravity filtrations (optional third media as needed)* • *Cartridge filters*
Coagulation stage	• *Retention time: Min. 20 seconds*
Flocculation stage	• *Retention time: Min. 20 minutes*
Clarification stage	• *Lamella surface loading rate: ≤ 1.0 $m^3/m^2.h$.*
Dissolved air flotation	• *Surface loading rate with recycling: 25 $m^3/m^2.h$* • *15% recycling*
Gravity dual media filters	• *Surface loading rate: < 7.5 $m^3/m^2.h$ with all filters operating* • *The top layer (Anthracite): 1.2 m* • *The bottom layer (Silica sand): 1.5 m*
Cartridge filters	• *Filtration size: 5 µm.* • *Construction material GRP* • *Cartridges: melt-blown polypropylene*
Chemical pre-treatment	• *Ferric chloride 5 – 30 ppm as pure chemical (jar test needed for ppm level)* • *Polymer (0.1- 0.5 ppm Lamella, DAF)*

Process Stage	Design Criteria (2 x 200 MLD)
	• *Pre Chlorination -Sodium hypochlorite (1-3 ppm)* • *Post Chlorination -Sodium hypochlorite (1-2 ppm disinfectant)* • *Sodium bisulphite (10 ppm)* • *Sodium hydroxide (pH control, 10 ppm)* • *Antiscalant dosage for SWRO (1 ppm)* • *Biocide for biofouling control*
Filtered water tank	• *Two tanks with interconnection proposed for both production streams with 2 compartments:* • *Tank Capacity - 10000 m^3 each (30 min)*
SWRO desalination streams	• *Two main streams (2x 200 MLD)*
SWRO membranes	• *30,720 units in operation. – 8 number per vessel* • *Mixed HR and LE membrane/PV allowed* • *Operating flux: 13.4 $l/h/m^2$* • *Diameter: 8", Length: 40", Area: 440 ft*
High-pressure feed pumps (Booster RO)	• *Design pressure: ~ 4 bar as per design requirement* • *With or without VFD as needed*
High-pressure pumps	• *Design pressure based on seawater max TDS and min Temperature* • *With VFD as per design requirement*
Energy recovery system	• *Isobaric pressure exchanger with high reliability.*
Booster pumps for energy recovery systems	• *Centrifugal mono-stage horizontal type or as needed.* • *Design pressure: ~ 2.5 bars or as per design requirement* • *With as per design requirement*
Recirculation pumps for energy recovery systems	• *Centrifugal mono-stage horizontal type or as needed.* • *Design pressure: ~ 2.5 bars or as per design requirement* • *With or without VFD as per design requirement VFD*
SWRO skids	• *Each RO train size – 25 MLD* • *Alternative quote for change in RO train size is allowed – valid reasoning with capital and O&M cost saving must be demonstrated.*
SWRO front permeate tank	• *2 tanks – one per stream interconnected* • *Each tank volume: 5,000m^3 per stream*
Post-treatment	• *Composed by remineralisation with CO_2 and limestone beds (at least 48% permeate to be treated)* • *pH adjustments with NaOH* • *Disinfection with sodium hypochlorite*
Limestone bed for remineralisation	• *Upflow / Continuous Feeding Limestone Remineralization system.*

Process Stage	Design Criteria (2 x 200 MLD)
	• *Number of cells: 28 units (14 per stream).* • *Surface loading rate:* 10 $m^3/m^2.h$ • *Contact time: 25 minutes* • *Integrated storage system for limestone with capacity for minimum 30 days* • *Air + water backwash system*
Product water tanks	• *2 metallic tanks for each stream* • *Total capacity 30,000 m3 (2 hours) – Each tank 15000 m3*
Clear Water Tank	• *1 RCC CWR with partition* • *Total capacity 9,000 m3*
Battery limit	• *2 Electromagnetic flow meters in-line* • *2 Sampling tap in between* • *2 drainage system in between to headworks*
Cleaning (CIP) and flushing system	• *Preparation Tank size : as per system requirement* • *CIP pumps flow:1152 m3/h* • *Flushing pumps flow: 1024 m3/h*
Wastewater treatment	• *physiochemical treatment. At least 1 sludge balance tank, 2 thickeners, 1 sludge holding tank and BFP building with up to 18 BFPs considering raw water TDS up to 300 mg/L.*
Specific requirements	• *Pre-treatment pilot plant* • *RO cleaning pilot plant* • *Membrane testing plant*

1.7 Works Life Expectancy

The Contractor shall design the Works for a life expectancy as follows:

- Civil works, buildings and buried pipelines: 50 years
- Concrete tanks, process chambers 50 years
- Heavy mechanical and electrical equipment 25 years
- Other mechanical and electrical equipment 15 years
- Buried earth electrode systems 30 years
- Automation and sensors equipment 15 years
- Control panels 15 years
- Instrumentation systems 15 years
- Metallic reservoir and tanks (not for seawater or brine) 25 years
- Polyethylene tank (or other chemical containers) 10 years
- Pressure vessels 30 years
- SWRO membranes >5 years

1.8 Turnkey Contract

The implementation of the construction works for the 400 MLD SWRO desalination plant at Perur shall be a 'turnkey contract'. Accordingly, the Contractor shall be required to execute the construction works followed by O&M of the Plant under DBO basis as per the performance requirements of the proposed Plant including civil, mechanical, electrical, and instrumentation components as specified in the Technical Specifications and elsewhere in the bid documents.

The scope of the successful bidders who shall execute the works and guarantee plant and process performance shall include, but shall not be limited to the following:

- All preparatory works including clearing, levelling and compaction of the site, site grading/ dressing of site as per specified formation or finished ground level (FGL), provision of access roads, roads inside and around the site etc., excavation, dewatering as required and disposal of all surplus earth to a suitable location.
- Necessary topographic survey and geotechnical investigation and any other investigation(s) which are considered necessary in the opinion of the Contractor as well as those deemed fit by the Engineer.
- Prepare process and hydraulic design with the layout and hydraulic flow diagram of the complete desalination plant considering two streams, to meet the product water quality parameters.
- Undertake complete detailed engineering design of the desalination plant including process, civil, structural works, mechanical (with intake/outfall pipings), electrical and instrumentation/ DCS system equipment and allied works with construction drawings, to ensure process performance, and submit for the approval of the Engineer and the Employer.
- After approval of the designs and drawings by the Engineer and the Employer, the Contractor shall commence implementation of civil, mechanical, electrical and instrumentation and allied works at the site.
- Placing of orders, manufacture, testing at the place of manufacture, inspection by the Employer's representatives/Engineer, finishing and painting, packing, transport, supply/delivery, storage, erection/ installation, testing and commissioning of the plant mechanical, electrical and instrumentation equipment as per the tender and with the consent of the Employer.
- Providing as-built drawings for all components in soft and hard copies.
- Contractor shall provide the operation and maintenance manuals for the Plant and shall update them regularly.
- Contractor shall provide all services required to operate the Plant successfully to meet the required product water quality.

The Contractor shall be responsible for all aspects of design and execution in order to meet the required plant performance and other conditions/standards laid down in the specification within the defined battery limits.

1.9 Perur Plant Design Philosophy

The Plant shall be designed and operated in 2 plant streams of 200 MLD each. The Contractor shall provide two fully separate streams in all respect. Only the intake pumping station, clear water reservoir and Outfall tanks will be common to both the streams. All pre-treatment units, RO system, post-treatment system, tanks and chemical storage and dosing systems shall be separate to both the streams. The detailed information is given in the indicative plant layout drawing provide in Part-2, Section VI, C2.

The Perur project is expected to be the spine of the water production for Chennai and will be operated at its maximal available capacity; therefore, it shall offer the lowest cost (CAPEX and OPEX combined) compared to the other desalination facilities.

Design at every stage shall optimise the Capex and Opex distribution, by using "Net Present Value" computation and implementing the best practices of desalination Industry. While aiming at reducing the Opex, a specific focus at energy consumption will be considered.

1.10 Uninterrupted Power Supply (UPS) Systems

The Contractor shall provide an uninterrupted power supply for plant instrumentation and control system. The Contractor shall demonstrate the operation of the UPS systems by actually simulating a plant-wide or localised power failure condition (as agreed with the Engineer) and proving that:

- all the process instruments have continued to measure the plant data
- the PLC has been processing these and posting the data to HMI
- the HMI has been performing with no interruption and continue to log and trend these data.
- all the instrumentations, including valves, are set in the fail-safe mode.

Refer to Part-2, Section VI, Document A-8 for detailed information of the UPS.

1.11 Plant Layout

Overall tentative layout for the entire Desalination plant shall be referred from Works' Requirement – Part-2 Section VI, C-2 enclosed. Final layout of the systems shall be furnished by the Contractor and finalised during detailing.

The general arrangement drawing as proposed by the bidder shall clearly indicate the dimensions of the various equipment, pipe routing, valve locations etc. The pipes shall be laid out in such a way that they are easily accessible for any maintenance or repair and also permits easy movement of the personnel. The exact layout considering the actual equipment dimensions, handling facilities, clearances as required for easy operation and maintenance, pipe support locations etc. shall have to be firmed up by the bidder for satisfactory operation of the systems covered under the scope of work. The flow of acid and alkali from bulk tanks to dosing tanks shall be by gravity, and hence the bulk chemical tanks shall be located on elevated saddles. All platforms and stairways shall have a minimum clear width of 1000 mm.

The drawing shall be prepared on standard-sized drawing sheets not larger than size AO (840 mm × 1190 mm).

1.12 Time for Works Completion

The whole of the Work, including mobilisation, reconnaissance, survey, sub-soil investigations, design, manufacturing, transportation, construction, installation, commissioning, testing and proving is to be completed within the scheduled Time for Completion as set out in the Part 3, Section VIII, Particular Condition (PC). The duration of the Preliminary Test period is 15 days, and the Proving Period is 30 days. The physical completion of the Works and Facilities in all respect followed by commissioning and process providing shall be completed within 3.5 years after the award of the contract. The O&M period for 20 years will start after the process proving and submission of all the required documents to the Employer, as explained in Part 3, Section VIII, Particular Condition (PC).

1.13 Milestones

The Contractor is to ensure consistent pro-rata progress on all components of the Contract during the entire Contract period. The key milestones set out in Table 5, or such other Milestones as may be proposed by the Contractor and agreed by the Employer at the time of bidding, are proposed to be adopted for periodic review of the progress of various components. These milestones will be the stages when the decisions regarding any delay in the implementation will be taken with a view towards the application of the provisions of Clause 8.7 of the Particular Conditions of Contract – Part 3, Section VIII.

Table 5: Milestones of Works Description for 400 MLD DSP

S. No	Work Description	Time (Months) from Date of Notice to Proceed													
		3	6	9	12	15	18	21	24	27	30	33	36	39	42
1	**Mobilisation**														
1.1	Establish site offices	100%													
1.2	Set up Site laboratory	100%													
1.3	Site surveys and investigations	100%													
1.4	Finalisation of the work plan	100%													
2	**Design and Procurement**														
2.1	Obtain design approvals	Start	50%	75%	100%										
2.2	Mobilise construction equipment		50%	100%											
2.3	Place orders for Plant and equipment		Start	50%	100%										
2.4	Procurement of plants and equipment		Start	25%	50%		75%		100%						
3	**Intake and Outfall Structures***														
3.1	Two Intake Headers			Start	50%				100%						
3.2	Laying of Intake Pipeline			Start	50%				100%						
3.3	Laying of Outfall Pipeline			Start	50%				100%						
3.4	Intake Well, Screen and Pump station			Start	25%	50%	75%	100%							
4	**Pre-treatment Structures**														
4.1	Inlet structure with flash mixer				Start	25%	50%	100%							

S. No	Work Description	Time (Months) from Date of Notice to Proceed													
		3	6	9	12	15	18	21	24	27	30	33	36	39	42
4.2	Coagulation and Flocculation Chambers				Start	25%	50%	75%	100%						
4.3	Lamella Settler				Start	25%	50%	75%		100%					
4.4	DAF				Start	25%	50%	75%		100%					
4.5	DMF				Start	25%	50%	75%		100%					
4.6	RO Feed Tank pumping station				Start	25%	50%	75%							
4.7	Chemical buildings				Start	25%	50%	75%	100%						
4.8	MCC Building				Start	25%	50%	100%							
4.9	Sub-station buildings				Start	50%	100%								
5	**RO System**														
5.1	RO Housing Structure				Start	25%	50%	100%							
5.2	CIP Tank						Start	25%	50%	100%					
5.3	Permeate Tank						Start	25%	50%	100%					
5.4	Neutralisation Tank						Start	25%	50%	100%					
5.5	Outfall Tank						Start	25%	50%	100%					
5.6	Limestone Filter					Start	25%	50%	75%	100%					
6	**Sludge Treatment System**														
6.1	Sludge Balance Tank						Start	25%	50%	100%					
6.2	Sludge thickeners						Start	25%	50%	75%	100%				
6.3	Sludge Holding tank						Start	50%	100%						
6.4	BFP building and service tank						Start	25%	50%	75%	100%				
6.5	Domestic Sewage Treatment							Start	25%	50%	100%				

S. No	Work Description	Time (Months) from Date of Notice to Proceed													
		3	6	9	12	15	18	21	24	27	30	33	36	39	42
6.6	Main control room with DCS								Start	25%	50%	75%	100%		
7	**Electrical and Mechanical Works**								Start	25%	50%	100%			
7.1	All Mechanical Works						Start	25%	50%		75%		100%		
7.2	All Electrical & Instrumentation Works						Start	25%	50%		75%		100%		
7.3	Main control room with DCS								Start	25%	50%	75%	100%		
8	**Power Supply Systems WTP including 33kV single circuit tower lines**														
8.1	Obtain design approvals		Start	100%											
8.2	Mobilise construction equipment			Start	100%										
8.3	Place orders for substations			Start	50%	100%									
8.4	Receive materials				Start	50%	100%								
8.5	Erect and install					Start	50%	100%							
8.6	Energise, test and commission						Start	100%							
9	**Commissioning and Testing**														
9.1	Commissioning and test run													100%	
9.2	Process Proving														100%
10	**Plant Road and Land Scaping**														
10.1	Mobilise construction equipment												100%		
10.2	Rough grading and earthworks												100%		

S. No	Work Description	Time (Months) from Date of Notice to Proceed													
		3	6	9	12	15	18	21	24	27	30	33	36	39	42
10.3	All-weather surfacing												100%		
10.4	Final grading and finishing													100%	

2. THE SITE DETAILS

2.1 Location of the Site

The proposed construction site for the Desalination plant is located at Perur village, about 40 km from the Chennai city centre. The total area of the plot is approximately 34 ha. It is situated along the coastal side of the East Coast Road (ECR). Its ground elevation is chart datum (CD) +2.0 to +7.5m with varying topography. ECR is approximately CD + 11m.

There are two numbers of graveyards identified within the proposed Site – one located on the Southern side of the sea coast and another on the Northern side towards the East Coast Road. It is understood that the graveyards must be left undisturbed and shall be protected by a compound wall all across and proper drainage shall be made draining towards the sea. Nevertheless, the unused area available at the proposed Site is enough for the construction of the proposed Plant in all respect. Overall tentative layouts for the entire Desalination plant may be referred from Generalised Site Layout enclosed in Part-2, Section VI-C2. The final layout of the systems shall be furnished by the Bidder and will be finalised during detailing.

The climatic conditions are characterised by warm dry winters (27^{o}C average daily max) and hot summers (39^{o}C average daily max) with an annual average rainfall of 1200mm. Cyclones are common in the area, and the Site is expected to be affected by cyclones.

The proposed land has been identified under survey number – 208/ 2B3 belonging to the M/s. Arulmigu Alavandar Nayakar Trust maintained by The Hindu Religious and Charitable Endowment Board (HR & CE) Department, Government of Tamil Nadu (GoTN). CMWSSB procured the land on a long term lease basis.

The site land profile is slopping from East Coast Roadside towards the seashore. The plant elevation @ CD +6.5 m is a minimum elevation required for such a large plant. So, the site land is needed to be developed by earth filling to maintain the finished ground level (FGL) at CD +6.5. The mean seawater level is at CD+0.65m. The construction of the Plant will be at FGL – CD +6.5.

2.2 Access to the Site

The proposed 400 MLD desalination plant is located on the coast of the Bay of Bengal. Regular access to the Perur site from Chennai is via the East Coast Road. The Site is located about 34 km South of the City Centre, along the East Coast Road.

The Employer will provide access to and limited possession of the Site to the Contractor for carrying out the Works. The Tenderer shall be deemed to have inspected the Site, including access before submitting his Tender.

The Contractor shall ensure that all the Plant offered is of a size and weight or can be divided into sections of a size and weight suitable for access to the place of installation/rehabilitation. Also, the equipment used for construction/installation purposes shall be able to gain access and position for such purposes.

The Nemmeli desalination plant is in the vicinity within 1 km of the proposed Site. The Contractor shall ensure that the operation of the Nemmeli plant and production of the clear water for supply to the city shall not be hindered any way due to construction works or mobilisation of the equipment, civil or any contract related works. The strategy of the work implementation shall be discussed with and approved by the Engineer before any work execution to avoid any unforeseen difficult situation.

2.3 Employer's Requirements

The Contractor shall use the indicative process design given in the Technical Specifications (Part-2) as a guide to understanding the Employer's requirements. However, the final process, mechanical, electrical and civil designs for the required performance of the complete design-build and O&M Works at the Plant with sludge treatment and waste disposal out of the site premises are the responsibilities of the Contractor. The bidders are encouraged to visit the proposed Perur plant site and understand the nature of works and level of site rehabilitation required for the plant construction and smooth operation as per Employer's Requirements. The successful completion of the full design-build Works and O&M Works as per the Contract is the responsibility of the Contractor. If additional works are essential which have not been mentioned in the bid document and Schedule of Costs, then the bidders must identify those additional works separately in the technical schedule and price schedule and include in their offered project cost accordingly.

2.4 Maintenance of the Site

The Bidders shall allow cost for maintaining the accommodation, equipment and all related services during construction, installation and operation of the works until the expiry of the Contract period or until such time as the facilities mentioned above, with the permission of the Engineer, are removed.

2.5 Areas outside the Site

In the event of the Contractor making use of any special or temporary wayleave or accommodation acquired by him or any tip for the disposal of surplus materials, or any borrow pit or quarry, he shall obtain the written consent of the owner, occupier or authority having charge of the land in which such wayleave, accommodation or tip is situated and shall make a record agreed by the owner, occupier or authority as aforesaid of the condition of the surface of that land before entering thereon.

In the event of the Contractor making use of any special or temporary wayleave or additional accommodation made available to him by the Employer for the purpose of the Contract, the land in which such wayleave or accommodation is situated shall be deemed to be part of the Site.

Under these circumstances, the Contractor shall form a Working Area extending five (5) m from the edge of the Permanent Works or accommodation on all sides. The Contractor shall restrict his activities to within this Working Area. On completion of the works in this area, the Contractor shall reinstate the area to its original condition and the satisfaction of the Engineer.

For the purposes of this Clause, 'accommodation' shall be deemed to include housing, offices, workshops, warehouses, and storage areas.

2.6 Road Works

The Contractor shall obtain all permits required for carrying out works such as excavation on public roads and shall liaise with the appropriate authorities with regard to the timing and execution of the road works. The Contractor shall be responsible for establishing and maintaining temporary road diversions for the duration of the road works. The road shall be kept open at all times during the road works period, and the work shall be carried out in such a manner as to minimise the disruption to traffic. All costs related to any type of the permissions needed during work execution shall be included by the Bidder in his price bid cost.

2.7 Maintenance of Existing Access Roads

The Contractor shall use existing access roads to the Site, which are necessary for the execution of the Works. The additional access road may be created with the consent of the Employer and after getting full permission from the concerned government authorities. The Contractor shall be solely responsible for the maintenance of the Site access roads. This responsibility shall continue until the completion of the Defects Liability Period, or until such earlier date as the Engineer may advise the Contractor in writing. Such maintenance work shall include general up-keep and any necessary repairs to the damaged road surfaces, pavement, drainage, associated slopes, etc. to original condition. While carrying out such maintenance work, the Contractor shall make arrangements to maintain through the passage for the Employer's and his staff's vehicles and also those of subcontractors over these access roads, which may comprise temporary diversions all to the approval and satisfaction of the Engineer.

The Contractor shall take every precaution while operating tracked or unsprung vehicles on surfaced roads and shall use planking or some other protective material to protect the road surface.

2.8 Clearance of the Site

The Contractor shall clear the Site to the extent required by the Engineer for checking the setting-out. Clearance of the Site shall also include the landfilling, excavation, demolition and removal of all trees, articles, objects and obstructions which are expressly required to be cleared to the satisfaction of the Engineer. The Employer will assist the Contractor in obtaining the necessary approvals and permits for removal of trees. However, obtaining such approvals and permits shall be the sole responsibility of the Contractor.

The Contractor shall remove the material arising from such clearance and dispose of it in a manner and at a location, on or off the Site, to the approval of the Engineer.

The Contractor shall not clear the Site of any structure without the prior written permission of the Engineer.

2.9 Clearance and Reinstatement of the Site on Completion

On completion of the Construction Works, the Contractor shall clear any temporary works areas and temporary access roads and reinstate the areas to their original condition/ required landscaping and to the satisfaction of the Engineer.

2.10 Site Records

The Contractor shall make records of the position and extent in the excavations of every type of services, stratum and obstruction encountered during the construction of the Works.

2.11 Access for the Employer and Engineer

The Contractor shall permit the Employer/Employer's representative, and the Engineer and any person authorised by the Employer or the Engineer including workers of the Employer, other contractors or utility undertakings access for the purposes of the Contract to all areas of the Site and any additional accommodation or temporary wayleave for the duration of the contract period.

2.12 Water Supply and Disposal on Site

The Contractor shall manage the supply of potable water for the purposes of construction of the Works. The Employer will assist in getting the water supply to the Site at the commercial rates. The distribution system at Site, including water meter for measurement of the quantity of water used from the point of supply, shall be the responsibility of the Contractor. The Contractor shall ensure the quality of the water remains suitable for the purpose for which it is intended and maintain the water meter in proper condition.

Wastewater shall be disposed of off clear of the Site to the satisfaction of the Engineer and the government authority so as to cause no damage or complaint. In any circumstances, the wastewater can't be discharged to the sea.

2.13 Latrines and Washing Facilities

Throughout the period of plant construction, the Contractor shall provide, maintain and cleanse suitable and sufficient latrines and washing facilities for use by his employees. He shall ensure that his employees do not foul the Site and make proper use of the restrooms.

Where practicable the latrines shall be connected to the nearest sewer, or if this is not practicable, the Contractor shall provide an adequately sized septic tank and soak away. The Contractor shall also provide separate latrines to the above requirements for the entire Employer's/Engineer's staff. After completion of the works, the latrines and washing facilities shall be removed, all ground disinfected and the surface reinstated to the satisfaction of the Engineer.

2.14 Electricity for Contractor's Use on Site

The Contractor shall be responsible for the provision of energy meter and distribution of an electrical supply at Site for the purpose of construction Works. The Contractor should acquire the electricity for Works through state power supplier at the commercial rate. The Employer will not be responsible for the availability and reliability of the electrical supply.

The construction and installation works shall comply with all the relevant regulations, Indian Standards and Codes of Practice, and Health and Safety requirements, etc. The Contractor shall take every possible precaution to ensure that his execution works are safe and injury to personnel or damage to Plant and buildings is avoided. The Contractor shall be fully responsible for all safety and maintenance aspects including the asset, personnel and material safety insurance etc.

The Contractor shall test the temporary Site electric distribution system, including energy meter every three (3) months for compliance with the relevant standards.

2.15 Camp and Office Facilities

The Contractor shall construct and maintain to the Engineer's satisfaction a camp to provide living accommodation for all Contractor's staff and operatives who have no other local accommodation. The Contractor's camp shall be located close to but not on the Site itself and at a location approved by the Engineer.

Responsibility for providing all services to the living quarters and compliance with all sanitary laws and other laws and regulations shall be borne by the Contractor. Security and the fencing of these areas shall be the responsibility of the Contractor.

2.16 Compressed Air Use on Site

The Contractor shall provide the necessary compressed air plant and equipment required for construction of the Works. Electrically driven compressors connected to the Site electricity supply shall not be used. Diesel engine driven compressors shall not be sited within buildings or at a location that may cause a health hazard to personnel owing to exhaust fumes or noise.

2.17 Refuse Disposal on Site

Refuse, and rubbish of every kind shall be removed from the Site and disposed of by the Contractor at his own expense, frequently and regularly so as to keep the Site in an approved wholesome and tidy condition to the satisfaction of the Engineer.

2.18 Health, Hygiene and Contamination of Water Supplies

The Site shall be an area of 'restricted operation'. Exemptions may be granted at the discretion of the Engineer for short-term operations involving no risk of contamination.

- All personnel shall be medically accepted
- Strict discipline shall be maintained concerning personal hygiene
- Vehicles, Plant, tools and protective clothing shall be kept clean and disinfected regularly

To obtain medical acceptance, the Contractor shall require his employees and those of his sub-contractors to undergo medical screening, to ensure that they are not harbouring waterborne pathogenic organisms, before commencing 'restricted operations'.

All potential employees and supervisors who may have contact with the 'restricted operations' shall take a copy of the completed questionnaire together with two colour passport size photographs to the Medical Officer for Environmental Health of the District Health Authority where the person resides.

The Medical Officer will consult the person and return the questionnaire to the Contractor. The Contractor shall then forward the questionnaires and photographs of those he wishes to employ to the Engineer for approval. Approval in the form of a blue identity card shall be issued for the approved cases. The card is valid for the duration of the Contract or one year, whichever is less. Contracts of duration greater than one year of 'restricted operations' carried out in the maintenance period will require a reassessment of employees.

If an employee contracts any illness, looseness of bowels or gastric disorder he must immediately cease work on 'restricted operations', return his identity card, avoid contact with other employees, undergo medical screening and gain fresh approval before continuing work on the `restricted operations' Site.

Works involving both 'restricted operations' and 'non-restricted operations' shall either require (1) all employees to be medically accepted or (2) separate messing facilities, storage for protective clothing, tools, vehicles and Plant for the two types of employees.

2.19 Safety and Security on Site

The Contractor shall at all times maintain a safe system of working and shall comply with all enactments, regulations and working rules relating to safety, security, health and welfare of all persons who may be affected by his work. In particular, the Contractor shall ensure that only persons who are appropriately trained for their duties are employed and that the correct tools and procedures are used.

Nothing which has been written into or omitted from this Employer's Requirements shall be taken to relieve the Contractor from his obligations under this Clause. No clause in this Employer's Requirements shall prevent the Contractor from drawing the attention of the Engineer to any feature of the Works which is not consistent with normal safety practices nor prevent him putting forward proposals at any time which would increase the safety of the installations.

Not later than four (4) weeks before work commences on the Site, the Contractor shall submit to the Engineer his comprehensive proposals relating to the safety, health and welfare of all his personnel on the Site.

The Contractor shall appoint a suitably qualified representative as Safety Officer who shall be responsible for the implementation of Site procedures as per relevant standards which shall include but not be limited to:

- safety
- working in hazardous areas
- permit to work
- fire and smoking regulations
- first aid
- warning signs
- trenching scaffolding and other construction structures
- safety barriers
- protective clothing and equipment

- safety training
- safety meetings and inspections
- health and welfare

The proposals shall be appropriate for all grades of labour and personnel who will work on or visit the Site on behalf of the Employer, Engineer or Contractor. The Engineer will have the power to stop any activity or work in any area where there is a breach of the published Site safety rules such that health or life is put at risk.

The Contractor shall, also, comply with the Safety Policy of the Employer, copies of which are available from the Engineer upon request.

The Contractor shall ensure that all employees and subcontractor employees working on the Site are not working in an unsafe manner to endanger themselves, the Contractor's personnel, other personnel or the Plant. The Contractor shall bring any violation of Site safety rules by others to the attention of the Engineer in writing.

2.19.1 PPE and Protection from COVID-19

The Contractor shall ensure that all the personal protective equipment (PPE) are available with each and every worker at the site. It should include:

- Respiratory protection - for example, disposable masks, cartridge, half or full face. It is important to protect workers from transmitting any infection such as COVID-19.
- Eye protection – for example, spectacles/goggles, shields, visors.
- Hearing protection – for example, ear muffs and plugs.
- Hand protection – for example, gloves and barrier creams.

2.20 First Aid and Life-saving Apparatus on Site

The Contractor shall provide on the Site such life-saving apparatus as appropriate and an adequate and an easily accessible first aid outfit or such outfits as required in any government ordinances, factories acts, etc., published and subsequently amended from time to time. Also, an adequate number of persons permanently on the Site shall be instructed in their use, and the persons so designated shall be made known to all employees by the posting of their names and designations in a prominent position on Site.

2.21 Electrical Safety on Site

The Contractor shall be responsible for the electrical safety of all Plant supplied and installed. Whilst any equipment is being installed or tested; the Contractor shall ensure that all necessary precautions are taken to safeguard personnel working on Site. If necessary, this shall include fencing off areas which are considered to pose a risk and erecting warning notices.

The Contractor shall be responsible for ensuring that the electrical installation is carried out by suitably trained competent personnel and that the work is carried out in a safe manner.

The Contractor shall be responsible for the operation on the Site of a permit to work system during the period of electrical equipment installation and testing. This system shall regulate the installation, the energisation and the use of electrical Plant installed and the method of work adopted.

2.22 Noise

The Contractor shall ensure that noise from the operations entailed in the construction of the Works does not cause annoyance to others working on the Site or to persons living adjacent to the Site.

2.23 Warning and Safety Signs

During construction of the Works statutory safety signs, shall be adequately provided throughout the Works, both indoors and outdoors. These safety signs shall be in Tamil and English and shall cover mandatory, prohibition, warning, emergency, fire-fighting and general notices. All signs shall be positioned around the Works at highly visible points. Provision of signs and the positions of signs shall be subject to the Engineers approval. Special attention shall be given to areas designated hazardous.

2.24 Site Working Hours

During the Construction Phase, no work shall be carried out on the Site on locally recognised days of rest, or outside regular working hours, unless:

(a) otherwise stated in the Contract

(b) the Employer gives consent

(c) the work is unavoidable or necessary for the protection of life or property or for the safety of the Works, in which case the Contractor shall immediately advise the Engineer.

The Contractor shall not increase the working hours during the Construction Phase without the prior approval of the Engineer. During the Operation and Maintenance Period, the Work shall be carried out all 24 hours of a day.

2.25 Delivery to Site

The Contractor shall be responsible for the transporting and handling of all the Plant as required. The storage of all equipment and construction items at the Site shall be the Contractor's responsibility.

The Contractor shall check all items against packing lists immediately on delivery to the Site and shall also inspect for damage and shortages. Damages and shortages shall be remedied with the minimum of delay.

The Contractor may, with the prior approval of the Engineer and at no extra cost to the Employer, make arrangements for any other contractor or agent to take delivery of, unload and store the Plant on the Site on behalf of the Contractor.

All deliveries shall take place during the Contractor's regular working hours.

2.26 Storage and Protection from Weather

Indoor storage for electrical, instrumentation equipment likely to be damaged due to moisture and outdoor storage for other plant equipment to be provided at Site for use by the Contractor for storage of Plant prior to erection will be subject to the approval of the Engineer.

The Contractor shall provide all other facilities for the safe and proper storage of Plant particularly cartridge filters, RO membranes, as recommended by the manufacturers, with particular consideration being given to temperature, rain, sunlight, wind and ground conditions the storage area shall be suitably raised to prevent waterlogging.

The Contractor shall remain responsible to the Employer for the care and insurance of the Plant, and the provisions of this Clause shall not relieve the Contractor of any of his liabilities under the Contract.

Stored Plant items shall be laid out by the Contractor to facilitate their retrieval for use in the programmed order. Stacked Plant items shall be protected from damage by spacers on load distributing supports and shall be safely arranged. No metalwork shall be stored directly on the ground. Small Plant items shall be held in suitable bins, boxes or racks and be clearly labelled. Items of Plant shall be handled and stored so that they are not subjected to excessive stresses, and so that protective coatings are not damaged.

The Contractor shall comply with the manufacturer's package and plant markings concerning the use and location of lifting slings, chains and hooks.

2.27 Contract Signboards

The Contractor shall supply and erect signboards at locations to be specified by the Engineer. The layout and dimensions of the signboards and their preparation shall be to the approval of the Engineer and the lettering in both Tamil and English shall be black on a white background.

2.28 Advertising

The Contractor shall not use any part of the Site for any form of advertising without the prior written approval of the Engineer.

3. PARTICULAR PROCESS REQUIREMENTS

3.1 Introduction

Through this tender, Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) intends to build a Seawater Reverse Osmosis (SWRO) based Desalination Plant of capacity 400 MLD at Perur, Chennai, Tamil Nadu, India to augment its drinking water supply capacity in the city of Chennai. At present two SWRO desalination plants at Minjur and Nemmeli are already in operation.

This project involves the construction of intake and outfall structure along with the required pipelines, construction of pre-treatment processes, SWRO desalination plant, remineralization plant, GIS-based electrical substation and other processes and units to build a complete operating plant within the plant premises for the production of 400 MLD potable water of the required drinking water quality.

Being a Turnkey project, the contractor has to do all the works for construction of a 400 MLD SWRO desalination plant including the data collection and studies, design, engineering, manufacture, supply, transportation to site, storage, construction, installation/erection, testing, commissioning and putting into the successful operation of the Plant on Design Build Operate (DBO) basis including all Civil, Structural and Architectural, Mechanical, Electrical, Control & Instrumentation and all Infrastructural work covering lighting, drain, all preparatory & temporary works for the purpose of meeting the entire scope of works.

The process design and construction work then O&M for 20 years shall be carried out for the 400 MLD desalination plant including the waste sludge treatment and waste disposal by the contractor. The Process design shall meet the Employer's requirements and be suitable to achieve the required performance while producing 400 MLD drinking water, under all raw seawater conditions.

3.2 Objectives and Scope

The scope of Works includes complete designing, construction, procurement, installation, commissioning and 20 years operation and maintenance of a 400 MLD SWRO desalination plant on Design, Build and Operate (DBO) basis. The Works include all process, mechanical, electrical, civil, instrumentation and control, and all other works required for construction of the plant with sludge treatment and water recovery facility. The Plant shall be fully automated and complete in all respect.

The Bidder shall be responsible for the design, engineering, construction/ manufacturing, shop fabrication, assembly, testing and inspection at supplier's works, packing, dispatch, shipping, delivery at Indian port/unloading at Indian port/delivery from Indian port to the site in case of imported equipment, and delivery/unloading at the site for indigenous equipment, unloading and storing at the site, insurance of all works, handling at the site, complete erection, start-up, commissioning, successful performance testing, process proving and handing over of the full package, warranty, and defect liability period.

Upon completion of the preliminary performance test and process proving, the Contractor shall be responsible for Twenty (20) years of the operation and maintenance of the 400 MLD plant on Design Build Operate (DBO) basis. The plant design, procurement, construction, performance test and process proving shall be monitored and certified by the Project Management Consultants (PMC) who will be acting as Employer's representative to support the Project Implementation Unit (PIU).

The Bidder shall include in its scope all the equipment, works and services necessary for completely safe and reliable operation and maintenance of the Plant in accordance with the terms of the DBO Contract, even if certain works are not explicitly stated in any part of the Tender Documents.

The detailed scope of works is presented in Part-2 Section VI-A1 Project Requirements.

3.3 General Arrangement of the Works

3.3.1 Site Details

The proposed construction site for the Desalination plant is located at Perur village, about 40 km from the Chennai city centre. The total area of the plot is approximately 34 ha. It is situated along the coastal side of the East Coast Road (ECR). Its ground elevation is chart datum +3.0 to +7.5m. ECR is approximately CD + 11 AMSL.

There are two numbers of graveyards identified within the proposed site. The one on the Southern side of the sea coast and another one on the Northern side towards the East Coast Road. It is understood that the graveyards must be left undisturbed and shall be protected by a compound wall all across and proper drainage shall be made draining towards the sea. Nevertheless, the unused area available at the proposed site is enough for the construction of the proposed plant in all respect. Overall tentative layouts for the entire Desalination plant may be referred from Generalised Site Layout enclosed in Part-2, Section VI, C2. Final layout of the systems shall be furnished by the Bidder and finalised during detailing. The climatic conditions are characterised by warm, dry winters (27^{o}C average daily max) and hot summers (39^{o}C average daily max) with an annual average rainfall of 1200mm. Cyclones are common in the area, and the site is expected to be affected by cyclones.

The proposed land has been identified under survey number – 208/ 2B3 belonging to the M/s. Arulmigu Alavandar Nayakar Trust maintained by The Hindu Religious and Charitable Endowment Board (HR & CE) Department, Government of Tamil Nadu (GoTN). CMWSSB procured the land on a long-term lease basis.

The details of the site details are presented in the Part-2, Section VI, D Site Data.

3.3.1.1 *Site Location*

The details of the local site conditions are given below in Table 1.

Table 6: Details of Site Location for the Proposed DSP Site

Particulars	Details
Site Location	District: Kanchepuram / Taluk: Thiruporur /

	Village: Perur
Site coordinates	12°42'44"N, 80°14'26"E
Nearest highway	State Highway SH 49, East Coast Road
Nearest railway station	Othivakkam railway station
Nearest Airport	Chennai Airport
Nearest town/ City	Chengalpattu, Pudupattinam, Tirukalukundram, Nandivaram-Guduvancheri
Archaeologically Important places	Mahabalipuram

3.3.1.2 *Topography*

Based on the preliminary onshore topographic survey and offshore topographic survey, the details are given below. However, the contractor has to repeat the study for confirmation.

<u>*Onshore topography*</u>

The Existing Ground Level (EGL) at the test conditions varied from +2.0m Chart Datum (CD) to + 3 m CD indicating the almost uniform condition. The site is having tree plantation of Casuarina. The site falls under Seismic Zone III as per BIS code IS: 1893 (Part I). The topography of the proposed Perur DSP site is furnished in Figure 1.

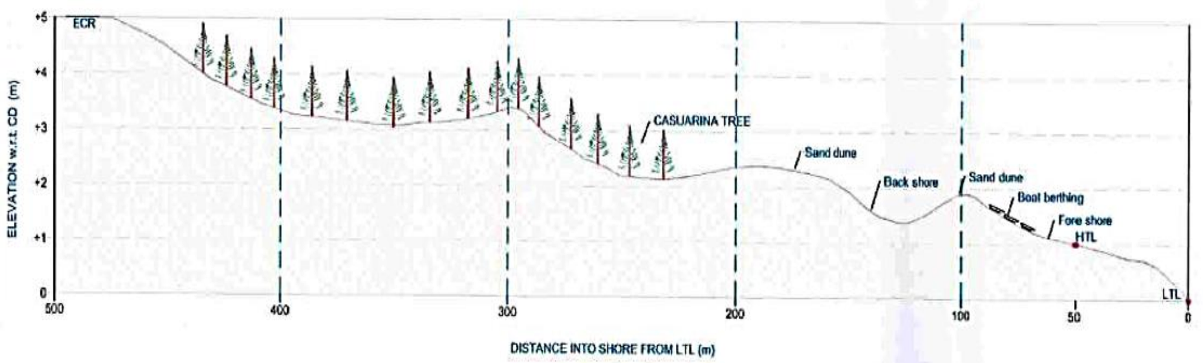

Figure 3: Typical Topography of Planned Perur DSP site

<u>*Offshore topography*</u>

Based on the bathymetric survey, buried rocks have been found near the shore that is spread in different direction and depth. Figure 2 presents a seabed map indicating the location of buried rocks.

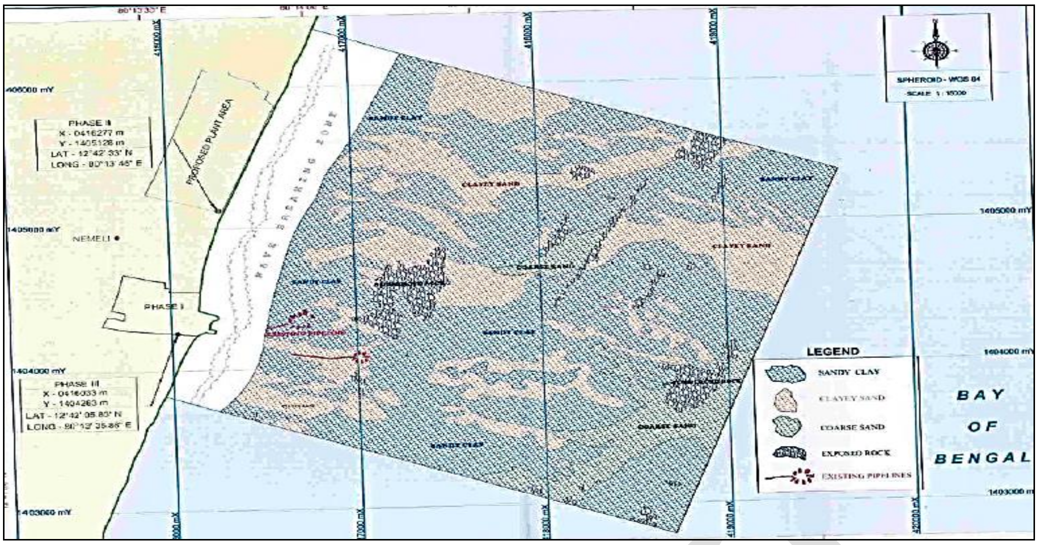

Figure 4: Seabed Map

The bathymetry survey shows that the depth contours are generally running parallel to the coast. The depth of the seabed with respect to the distance from the shore as obtained from the DPR report is furnished below in Table 2.

Table 7: Variation of Sea Depth with Distance from Shore

Depth w.r.to CD (m)	Distance from Shore (m)
2	150
3	200
4	225
5	340
6	440
7	520
8	660
9	835
10	1040
11	1360
12	1890
13	2160
14	2480
15	2720
16	2950

Sedimentary layers of silty sand were identified between – 0.0 and -8.0 m below the seabed.

3.3.1.3 *Climate*

Chennai features a tropical wet and dry climate. Chennai lies on the thermal equator and is also coastal, which prevents extreme variation in seasonal temperature. For most of the year, the weather is hot and humid. Typical meteorological data for Perur DSP is furnished below. Cyclones are more common in the Bay of Bengal, and the proposed Perur site is expected to be affected by cyclones by approximately 3 times per year. The details of Typical Meteorological data for Perur DSP site are furnished in Table 3.

Table 8: Typical Meteorological Data for Perur DSP

Meteorological Parameters	Unit	Values
Mean Ambient temperature (min./ max.)	° C	24.5 / 33.5
Barometric pressure	K Pa	100.1/ 101.35
Relative humidity (min./ average/ max.)	%	57 / 70 / 83
Main wind direction		Southwesterly
Average Annual rainfall	mm	1200
Average rainfall during Northeast monsoon (June to September)	mm	440
Average rainfall during Southwest monsoon (October to December)	mm	760
Maximum rainfall within 24 hours	mm	346.6

Source: Indian Meteorological Department Chennai, Meenambakkam, 1981- 2010

3.3.1.4 *Ocean Conditions*

The oceanography of the region is influenced by 3 climatic conditions viz., Southwest monsoon (June – September), Northeast monsoon (Mid – October to Mid – March) and a fair-weather period (Mid -March to May). The coast is more influenced by the Northeast monsoon than the other two seasons. Wave action is high during the Northeast monsoon and cyclonic period. The coastal current within a 5 km radius distance is greatly influenced by winds and tides. The nearshore remains more dynamic and turbulent due to persistent action of seasonal wind, high waves and sea currents. The distribution of temperature and salinity indicates that the nearshore water is well mixed without stratification. The influence of littoral drift is significant, and the annual net drift takes place in a northerly direction. The tide elevation at Perur with reference to Chart Datum (CD) is furnished in Table 4 below:

Table 9: Tidal Elevation at Perur

Tidal elevation	Chart Datum (CD) in m	RL (m)
Mean High water spring	1.15	RL 0.5
Mean High water neaps	0.84	RL 0.2
Mean Sea Level	0.65	RL 0.0
Mean low water neaps	0.43	RL -0.22
Mean low water spring	0.14	RL -0.51

Note: Onshore survey levels are recorded as m above sea level. Hence, the mean high water springs conversion of CD to MSL is 1.15 -0.65 m = RL 0.5.

3.3.1.5 *Geotechnical data*

A geotechnical survey was carried out on behalf of CMWSSB during the year 2014. The subsoil is made up of three distinct layers, as indicated below. However, the Contractor is required to undergo the geotechnical study to conform the values.

- Greyish silty fine sand : From - 0.0 to – 10.0 m (SPT N value = 10 to 64)
- Brownish silty stiff clay : From - 10.0 to – 13.0 / - 15 m (SPT N value = 7 to 9)
- Soft Disintegrated Rock : From - 13.0 to -15 m to – 19.0 m (SPT N value ≥ 100)
- Hard granite rock : From -17m to -23 m

Note: SPT – Standard penetration test

The groundwater table readings were recorded between 28th October 2014 to 5th November 2014. The groundwater table was encountered within depths of 1.54 m to 1.72 m below the EGL. In general, the groundwater table was almost consistent with the ground surface undulations, which implies that the groundwater is not perched water.

3.3.1.6 *Land Development Plan*

The height of the project site varies from CD +7 m on the East Coast Road to +2-3 m on the seashore side (Figure-3). Hence is it proposed to raise the site by additional earth fill to realize the Finished Ground Level (FGL) at CD +6.5 m. Raising of Finished ground level (FGL) up to +6.5 m CD is warranted to maintain safety factor to protect from strong winds and global warming and an additional 1.5 m considered for Tsunami and other emergency conditions. The boundary of the Perur DSP will be constructed on the raised land with 3 m high retaining wall of reinforced concrete. The retaining wall is proposed with pile foundation to keep it stable. Figure 3 presents the proposed land development plan for the proposed Perur DSP. The empty land on the right-hand side near intake may be used and included under boundary.

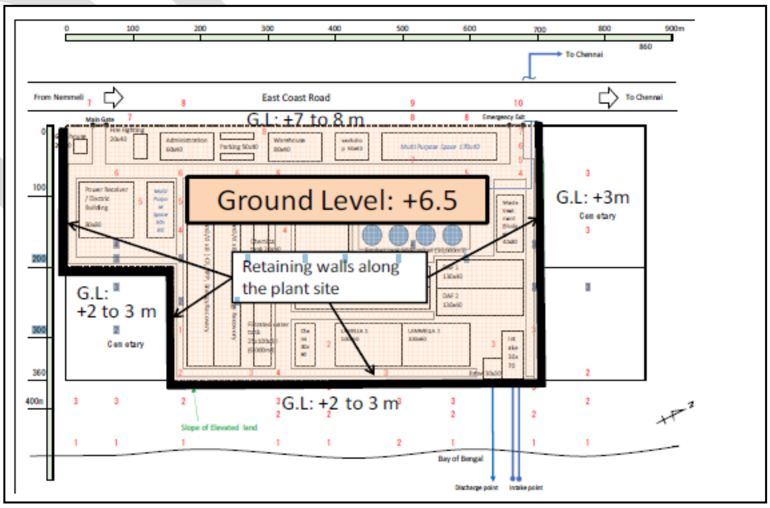

Figure 5: Proposed Land Development Plan for Perur DSP

3.3.2 General Arrangement of Plant

It is expected that the Contractor will use his best efforts to optimize the use of Plant land area.

A preliminary Plant layout of the desalination plant is shown on drawing 'General Layout Site' Part-2 Section VI, C2. The proposed Plant layout is a preliminary layout and is subject to optimization by the Bidders during the preparation of the Tender as well as during detail design. The following general rules shall be followed in arranging the Plant units:

The following general rules shall be followed for any construction work of the Plant units (to be erected):

- Sufficient space (of not less than 2.0 m wide) shall be allowed between items of Plant and adjacent Plant or fixed structures to permit safe and convenient access for operation and maintenance, and provision of appropriate structure foundations. The space between buildings shall be at least 5m to allow movement of the vehicles.
- In the case of areas that require movement of heavy equipment for installation and replacement, sufficient access shall be provided by the Contractor to move heavy vehicles. Adequate space shall be provided adjacent to all mechanical equipment as maintenance lay down area.
- Fixed ways, lifting eyes or other means shall be provided to permit the removal of Plant equipment that may logically be required to be removed during the course of its normal operational life for maintenance or any other purpose.
- Areas where the leakage is likely to occur whether in normal use or during maintenance, shall be provided with an underground drain line or covered RCC drainage channels which shall direct the spillage to a sump from where it can be pumped to the neutralization pit or standard outfall of the plant as per the quality of the leaking fluid.
- Where necessary, Plant shall be provided with removable acoustic coverings to limit the noise produced during normal operation to the specified limits.
- The Plant shall be arranged, and the buildings shall be designed to permit the removal/relocation of Plant items.
- The drain valves from process units with a diameter up to and including 250 mm shall be operated manually and those greater than 250 mm valve shall be operated by an electric motor. For the valves located below ground level, an extended spindle shall be provided for ease of operation.
- The yard pipelines should be laid underground and all flowmeters and dismantling, isolation valves should be kept underground in chambers with the display above ground to avoid any hindrance in the passage of vehicles.
- Chemical pipework shall be secured to racks or trays to be fixed to duct walls or walls of tanks and buildings as necessary. The method of securing the pipes to the racks shall be by clips or something similar, facilitating ease of removal in such a way that individual runs can be changed without dismantling adjacent pipes.
- All chemical pipes shall be colour banded and suitably labelled to enable individual lines to be identified throughout their run. Particular attention shall be paid to the layout of the chemical pipework, which shall be functional and neat in appearance. Generally,

where pipework is installed in ducts, it shall be supported not less than 150 mm clear of the floor.

- When selecting materials for pipework, the Contractor shall consider the deteriorating effect of some of the synthetic materials due to the action of ultraviolet light. Where such materials are employed, they shall be shielded from direct sunlight.
- Chemical storage should be grouped for compatible and non-compatible chemicals with separate bunding.

The Contractor shall ensure that all designs and equipment for which he is responsible, are safe, feasible and durable. Nothing in this Works' requirements shall remove the Contractor's obligation from drawing the attention of the Employer's Representative to any feature of the Works which is not consistent with safety or to prevent him making proposals for incorporating equipment or designs which would increase the safety of the Plant. The installation layout and plant design shall not allow any item of plant to be so positioned that danger to operating personnel could arise during normal operation and maintenance. Particular attention shall be paid to the position of pipes, air vents, electrical cables and rotating machinery. All rotating shafts, couplings, gears, flywheels, belt drives or other moving parts shall be fully guarded. Guards shall be designed to provide ready access to bearings, grease points, thermometer sockets/instrument probes and other checkpoints and to allow safe routine observation and servicing to be executed without the need to dismantle any part of their structure.

3.4 Plant Process Specifications

3.4.1 Seawater Quality

The Contractor shall consider the following raw water quality for the design of the desalination plant. However, the Bidders are advised to analyse and confirm the seawater quality to provide a suitable pre-treatment system design. The range of the parameters presented in Table 5 below provides the minimum quality range for the plant design.

Table 10: Seawater Quality

Parameters	Minimum value	Mean value	Maximum value
TDS, mg/l	32000	36000	39000
pH	8.00	8.13	8.20
Temperature, °C	26.0	28.3	31.5
Boron, mg/l	3.2	3.53	3.80
Turbidity, NTU	1.0	12	150
TSS, mg/l	10	75	300#
Total Organic Carbon (TOC)* mg/l	3.0	5	8

*Assumed values – need to be confirmed by the bidder.

TSS value may be higher than the maximum value during the Monsoon period.

3.4.2 **Product Water Quality**

The water quality requirements in product water tank shall meet the following parameters and the Indian Standards IS:10500-2012.

Main parameters relevant to the desalination process is furnished below:

- Turbidity (NTU) < 0.5
- Chlorides (mg/l) < 250
- TDS (mg/l) < 450 at plant potable water tank exit
- Boron (mg/l) < 1 mg/l all the time
- pH 6.5<pH<8.5
- LSI > Positive
- Hardness ≥ 80 mg/l as $CaCO_3$

3.4.3 **Intake and Outfall System**

Two number of HDPE intake pipes and one outfall pipe each of 2500mm OD at pressure rating of minimum 6.5 bar shall be provided. Each intake pipe shall cater to half the intake flow to produce total 404,000 m3/day of permeate water plus 10% extra flow to accommodate for biofouling/incrustation in the intake pipe. The intake shall comprise of two intake heads linked to the intake pumping station by two intake pipes laid below the seabed with the required cover using a pipe jacking/ TBM or suitable pipe laying method. The pipe shall pass manufacturing and installation quality controls subject to the Employer's inspection and approval. The intake head shall be made of concrete and comprise a number of vertical openings located between the seabed and seawater surface. The hydraulic analysis for the pipes shall allow for the marine growth of minimum 100 mm on all internal surfaces of the pipes. The intake and outfall pipes shall be laid on the same alignment as much as possible to avoid repeated trenching on different alignments.

The intake shall be provided with the state of art facilities to enable the pipelines to be pigged at the increase in pressure drop along the pipelines or the event of any sort of pipe blockage, preferably without the intervention of the divers entering the Intake system for manual cleaning. The pigging system shall be achieved by the provision of a pull line (launching station) linked to the pig entry point and delivering endpoint. The intake head could be provided with a removable cover at or above the seawater surface, and mounting point for a winch which could then be used to pull the pig. It should then be possible to recover the pig through the removable cover and to simultaneously provide a new pull line for the next pigging operation. As the pigging system and divers as needed will be provided by the Contractor, these needs to be priced in the price bid by the bidder.

3.4.3.1 *Intake Head*

A 100 mm screen with frame in Duplex Steel 2507 and bars in Cu Ni shall be provided at the intake to exclude larger marine life. One intake chamber and screen shall be provided on each conduit. There shall be two intake heads with screen offshore separated by a minimum distance of 3000 mm. The screens will be of >8.5 m diameter, ≤1.5 m high, starting at >3m above the seabed, in ≥ 10-metre depth of seawater at low tide. The approach velocity shall be ≤0.12 m/s to minimise the entrapment of marine species.

A fishnet will be provided to minimise the ingress of jellyfish to the intake. Provision shall be provided to inspect and replace the net from time to time, as the same is likely to be damaged by marine lives. The head loss through the intake system will also be monitored. In any increase in system losses indicating fouling at the intake, or the growth of biomass within the intake conduit, the same shall be cleaned through pigging.

3.4.3.2 *Intake Pipeline*

Two intake conduits, each of 2500mm OD at pressure rating of minimum 6.5 bar, shall extend into the sea where the seawater depth is at least 10 m below the Lowest Tide Level. Water will enter into the intake head opening at >3 m above the seabed and minimum 4 m below the top seawater surface during the low tide. The present study indicates that a length of 1700m outfall from seashore with intake at about 1200m, will be suitable to avoid mixing of brine discharge from 400 MLD Perur plant and also two Nemmeli desalination plants located in the close vicinity. However, the actual length of the pipeline will be determined based on the brine diffusion analysis by the Contractor and acceptable to the Employer's representative. The velocity in the conduit at peak flow shall not exceed 1.5 m/s. Friction losses at this velocity should be less than 1.5 metre head in the pipeline. Incrustation thickness in the pipeline shall be taken 100 mm for calculating friction losses due to the marine growth on the internal periphery of the pipeline. The velocity of water through the intake head openings should be ≤0.12 m/s. The height of the vertical openings shall not exceed 1.5 m. A fish net shall be provided outside the bared head opening to prevent the ingress of fishes.

Pigging system to restore the hydraulic capacity of intakes shall be provided as discussed above to safely clean the intake pipes with better efficiency (a few days per year compared to a few weeks) that serves, of course, the Availability Factor. At least two pigs shall be provided to accelerate the cleaning process.

The bidder needs to provide the detailed Head loss calculation of intake pipes from Seawater intake head to the onshore screen intake chamber and to determine the available water levels in the Screen upstream and downstream and the pumping station. The bidder needs to submit the detailed calculation with a head curve along with the intake and outfall system. If the same is not offered, the bid may be considered as non-compliance.

3.4.3.3 *Outfall Pipeline*

One outfall pipe will be provided with 2500 mm OD of the same material as the Intake pipe. For a peak outfall flow of up to 640 MLD, the velocity in the pipeline should be within 1.5

m/sec.

The Contractor shall design the outfall system based on the dispersion model to be conducted by him to promote better brine concentration management as per the environmental guidelines. The present study indicates that the brine discharge is suitable through 30 nozzles (diffusers) of each 0.35m opening installed on the pipe length with 6m spacing. However, the final outfall position shall be determined after the brine dispersion analysis by the Contractor and acceptable to the Engineer / Employer's representative.

3.4.3.4 *Intake Screening Station*

Seawater intake well will receive the seawater from the offshore intake head under gravity and transfer the seawater to the pre-treatment section. Seawater intake well will have two chambers separated by partition walls. The water production capacity of each of the chamber will be a minimum of 200 MLD. Whenever required, either one of the two chambers can be maintained, cleaned, or repaired while the other chamber in operation. So sufficient stop logs/ sluice gates shall be provided to isolate one of the two chambers.

The intake well houses Travelling Band Screens which pass water to the pump chamber. A minimum of 4 (3W + 1S) screens, shall be provided for the proposed 400 MLD product water plant; such that the full screening capacity is available even 33% of the screen is out of service. Each screen shall be provided with a dedicated screening chamber which can be isolated from the rest of the screening station. Isolation shall be by sluice gates only. Stop logs are not acceptable. Sluice gates shall be provided both on upstream and downstream of each screen chamber.

The screens shall be automatically cleaned and washed. Facilities shall be provided to enable an individual screen chamber to be drained entirely for maintenance.

Either the differential head loss across the screens shall be continuously monitored, or both the upstream level and downstream level shall be continuously monitored, and the differential head continuously derived.

The velocity across the screens shall not exceed 1m/s with the maximum design intake flow rate and the minimum seawater level. The screen mesh size shall not exceed 3 mm. The design should be such that it shall be possible to completely drain a single screen chamber from maximum tide level within 4 hours. The screens shall be made of materials suitable for the seawater use during plant lifetime and shall be structurally designed to withstand the maximum head-loss across the screens.

The differential head across the screens shall be recorded and used to initiate screen cleaning & washing automatically. In the event of the high differential head across the screens, an alarm shall be raised in the control system and the intake pumps shall be tripped by hardwired means. The trip differential head shall be less than the maximum structural design head-loss across the screens.

3.4.3.5 *Intake Pumping Station*

The screened water from the inlet screens shall flow into the intake pumping chamber. A minimum of (6W + 2S) pumps shall be provided for the total plant capacity (4 pumps for each process stream). Pair of 4 pumps shall form one manifold to supply water to one stream of 200 MLD plant. The bidder shall provide the no flow level in the pump well and hydraulic grade line entering into the pump station at both low and high tide conditions at the total inflow of seawater to produce 404 MLD RO permeate at 42% to 46% RO recovery. The static lift at Mean Low Water Springs and Mean High Water Springs shall also be provided.

Vertical Turbine pumps with large clear passages shall be provided in an RCC building where the motors shall be stationed on the first floor and pump discharge header at the ground floor to facilitate easy maintenance. The pump motors shall be with variable speed drive. The material of the pumps will be super duplex stainless steel (PREN No ≥ 41).

It shall be possible to isolate individual pumps for maintenance, whilst the remaining pumps are in service. The height of the pumping and screening chamber shall consider the maximum surge level which can be caused when all the pumps suddenly stop, with the seawater at maximum tidal level, and shall ensure that there is no flooding or damage to equipment under these circumstances. The standby pump shall automatically start in the event of failure of any of the duty pumps.

The bidder is required to carry out a transient analysis of the intake structure to determine the surge levels induced by a pump trip, and a pump starts and provides all calculations in connection of the same before start of intake pump station construction. The system shall be designed considering parallel operation of pumps.

The total flow-rate of water delivered by the pumping station shall be continuously monitored by two Electromagnetic Flow Meter – one in each process stream. All electromagnetic flowmeters in the plant shall be provided with a bypass line with sufficient isolation valves and dismantling joints to facilitate easy maintenance of the flowmeters.

Local indication of pump discharge pressure shall be provided. Low-level probes shall be provided in the pump well. The temperature, pressure, conductivity, oil, turbidity and chlorine residual in the pump discharge header shall be continuously monitored. The residual chlorine shall be measured at the outlet of pumping main and provision of suitable alarm shall be made in case of higher concentration.

3.4.3.6 *Shock Chlorination System*

A shock chlorination system shall be provided to inject sodium hypochlorite at the intake heads to minimise marine growth at the intake screens and in the intake conduits. The hypochlorite solution shall be injected across the intake head openings using a dosing sparger. All required system and piping shall be provided by the Contractor, including the provision of air pipe at the intake head offshore for the removal of entangled Jelly Fish on an intermittent basis. Suitable air system with compressors and air storage vessels shall be provided on shore for this purpose. The system shall be designed for maximum chlorine residual in the conduit up to 12 mg/l for 2 hours per day. The material of construction for the system shall be titanium or comparable.

Chlorination system shall also be provided to dose in the intake pump discharge line to reduce the tendency of bio-growth in the pre-treatment system.

3.4.4 **Pre-treatment System**

There will be two separate streams of the pre-treatment, desalination and post-treatment processes - each for 200 MLD product water capacity. The pre-treatment shall consist of a three (3) stage pre-treatment process to ensure sufficient safety in case of adverse Seawater quality conditions.

- Coagulation/flocculation followed by Lamella Settlers as the first stage,
- DAF (Dissolved Air Floatation) system as the second stage and,
- Gravity Dual Media Filtration system (DMF) as the third stage,

The design of the above processes shall be proven for similar application of salinity, temperature and silt and organic matter burdens. This configuration is mandatory, and a pre-treatment design consisting of only one or two process stage is not acceptable.

Provision should be provided to allow by-pass of DAF during the period of good seawater quality. However, the process design should consider this treatment scheme to be operated continuously throughout the year.

The pre-treatment process shall be reliable to achieve the guaranteed characteristics of seawater suitable to feed the RO Plant. The Silt Density Index (SDI) after DMF shall be <3.0 (95th %ile) and <4.0 (100th %ile) and in any case will not exceed the value recommended by any of the proposed membrane manufacturers. SDI tests shall be performed in compliance with ASTM D 4189 standard with Millipore filters.

The pre-treatment shall minimize the risk of organic and biological fouling and inorganic scaling on membrane surfaces and any damage to the membranes on account of residual chlorine in the pre-treated feed water.

The Bidder has to carry out his seawater testing/analysis to determine the raw water properties in order to ensure that the pre-treatment design offered is suitable to achieve the required treated feed seawater quality for RO system. The raw seawater quality provided above in Clause 3.6.1 provides the minimum range for the plant design. The bidder shall take full responsibility for any water analysis and plant design within his proposal. The employer shall not be liable for the accuracy or otherwise of the data and takes no liability for any water analysis and plant design.

3.4.4.1 *pH Stabilization*

The raw sea water will be dosed with sulphuric acid in the intake pump discharge line to achieve the optimum pH for coagulation. All concentrated sulphuric acid piping shall be Carbon steel and valves shall be Plug valves of Alloy 20 and butt-weld fittings shall be used. The tank should be carbon steel. Carbon content should be less than 0.25%.

Sulfuric acid chemical storage should be equipped to prevent air moisture reaching the chemical storage tank by the use of desiccant on venting and overflow pipes. All tank outlet nozzles should have double isolation valves. The pH of the dosed water shall be continuously monitored. An alarm shall be raised in the event of the dosed water pH being outside of acceptable limits.

3.4.4.2 *Inlet Chamber*

Each half process stream of 200 MLD product water will start with an inlet chamber followed by flash mixers. Coagulant will be added in this chamber. The flocculant (polymer) shall also be added after coagulant addition for better flocculation. The flash mixer will be a stirred tank (~100 rpm) of sufficient capacity. At least two flash mixing tanks shall be included for proper mixing with total residence time at least 20 seconds. Its design will be such that short-circuiting is eliminated and the coagulant is thoroughly mixed with the seawater.

3.4.4.3 *Coagulant*

The natural particles causing turbidity are negatively charged and repel each other, thus resulting in high stability. In order to be removed, these particles must undergo a destabilization step which is achieved by the use of suitable coagulant. The coagulant injection should be done after pH adjustment and before a dedicated flash mixing chamber. Coagulant should be ferric chloride, the purity of the product should be compatible with RO membrane application especially with regard to heavy metals/pesticides as well as must comply with the discharge norms of sludge/ solids.

Coagulant equipment should be made of plastic material resistant to UV light. Coagulant piping shall be schedule 80 cPVC/HDPE. The coagulant preparation and dosing tanks shall consist of three RCC Tanks. Each tank will be designed for 8 hours of service at the maximum dose rate. The coagulant and flocculant tanks shall be housed in a chemical building with RCC service water tank above the building.

The drive motor shall be equipped with a variable speed drive to vary the speed of the drive mechanism. The design torque for the drive mechanisms shall be a minimum of 200% of the continuous torque. All gears shall be enclosed in housings. The details of the civil and mechanical works are provided in the civil and mechanical specifications.

3.4.4.4 *Flocculant*

Flocculation is designed to generate large aggregates that can easily settle or float. It promotes an increase in the probability of inter collision of the small particles formed during the coagulation stage so as to generate larger aggregates.

The flocculation must be done in the flocculation tanks before the Lamella Settlers. The residence time for flocculation will be at least 15 min. Provision shall be made to dose polyelectrolyte downstream of the ferric chloride and before Lamella settler and DAF.

Flocculation will be achieved in two flocculation tanks in series with each tank consisting of one or two vertical mixers so as to have the mixing energy tapered.

Piping should be made of plastic material resistant to UV light.

The Contractor shall provide at least 1200mm wide platform with GI plate and 304 SS railings along with the Inlet Chamber, Flash mixer, flocculation tanks for close inspection of flocs formation. The Contractor shall make necessary arrangements to provide safe access for the maintenance of flash mixers, gates.

The flocculation tanks shall have tapered bottom with hopper to discharge any sludge accumulation in the tanks.

3.4.4.5 *Lamella Settlers*

Lamella settlers consist of a series of inclined parallel tubes through which the water passes. The inclined settlers significantly reduce the TSS concentration in water. But it is only partially successful in removing the larvae, algae and jellyfish particles off neutral buoyancy. These materials will be removed effectively by the DAF and media filtration downstream of the Lamella Settler.

The Contractor shall provide integrated self-standing settling tubes made of GRP/FRP/HDPE with 55^o-60^o inclination. The Lamella tube settler loading rate shall be <1.0 m/hr for better clarification of suspended solids. The Lamella settler and supports shall be of RCC. The bottom of the setter will be hopper type having 45^o side walls with sluice and knife valves as needed. The sludge of the settler will be directed to the standard sludge balance tank under gravity. The diameter of the pipe will be suitable for the sludge transfer without any blockage in the pipeline.

The Settler unit shall be complete with a self-supported access bridge or access bridge supported by the concrete tank. The access bridge shall be designed to safely withstand a live load plus any applicable dead loads and torque and wind loads. A maintenance platform complete with grating and SS316 handrail shall be provided around the drive assembly. The bridge material and coating systems, if applicable, shall be selected to withstand the marine environment. Grating shall be of GRP of functional strength to withstand live load plus any appropriate dead loads and torque and wind loads. The inlet chamber and internal feed pipe will be supported with tie-rods or truss supports that do not interfere with the rake or skimmer mechanism.

Table 11: Indicative Design Parameters for the Lamella Clarifier

S. No.	**Parameter**	**Unit**	**Values**
1	Minimum recovery	%	97-98
2	TSS removal	%	90-95
3	DOC removal	%	30-40
4	Tube Settler loading rate	m^3/m^2 h	< 1
5	Mechanism of sludge removal	-	Hopper bottom
6	No. of tanks	-	36 (18 tanks in each stream)

7	Tube settler material	-	HDPE/GRP
8	Shape of tube deck	-	Hexagonal-Chevron
9	Angle of inclination of tubes	degrees	55-60

3.4.4.6 *Dissolved Air Flotation*

Dissolved air flotation (DAF) is a process of liquid-solid separation by upward displacement of particles insoluble in water such as oil or solids. The removal is achieved by dissolving air in the water under pressure and then releasing the air at atmospheric pressure in a flotation tank basin. The released air forms tiny bubbles which adhere to the suspended matter, causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device. This process has an advantage, especially in terms of algae removal.

Raw water that has first been flocculated enters the bottom of the structure in a chamber where it is put in contact with pressurized water distributed uniformly across the width. Particular importance should be given to the distribution of the pressurized water (source of the microbubbles) and the water to be treated to ensure that floc is not broken during the process. The sludge accumulated on the surface is removed periodically by scraping or hydraulics removal while treated water is collected at the bottom of the Dissolved Air Flotation area. The clarified water is collected downstream of the work under drilled pipes. Air-water contact is achieved in a pressure vessel.

There will be at least 12 DAF tanks – 6 tanks in each plant stream of 200 MLD. The design of the DAF should take into consideration that one DAF cell is always out of service for maintenance. If some equipment are common to multiple DAF cells, then additional standby equipment shall be provided.

The size of particles in seawater is much smaller than in freshwater particularly during algae bloom and so, the average bubble size will be selected within 10-20 μm which can be adjusted to particle size in seawater to be captured. The minimum recycling rate shall be 15% for better particle agglomeration and removal. The DAF design shall be suitable to remove up to 95% of the suspended solids. The surface loading rate will be within 25 $m^3/m^2/h$. Based on the raw seawater quality, the Bidders have to understand the importance of DAF in the presence of upstream Lamella Settler and decide on the loading rate. In case opting for higher loading rate, the Contractor must demonstrate at least TWO operating reference plant (each ≥100 MLD) handling the similar seawater quality successfully.

Most of the suspended particles will be removed in the Lamella Settler. DAF is an additional barrier to remove the suspended particles and organics in the seawater. The purpose of providing the DAF is to remove the light particles which are not captured in the Lamella settler. Provision of coagulant and flocculant addition before DAF shall be provided to enhance the removal of the light particles during difficult seawater quality situation such as during the presence of oil and fats, organics and algae particles. A bypass line shall be provided to bypass the DAF when raw seawater quality is good.

The indicative design of the DAF is given in Table 7 below.

Table 12: Indicative Design Parameters for the DAF

S. No.	Parameter	Unit	Values
1	Minimum recovery	%	98-99
2	Flotation loading rate	m^3/m^2 h	20-25
3	White water recirculation flow	%	15-20
4	Air Saturator Efficiency	%	90-95
5	Air Saturator Pressure	kPa	800-900
6	Minimum tanks	No.	12 (6 tanks in each stream)
7	TSS removal	%	85-95
8	DOC removal	%	15-25

3.4.4.7 *Gravity Dual Media Filters*

Dual Media Filters (DMF) is a process of liquid-solid separation by media filtration. Clarified water from the DAF outlet shall feed to the inlet channel of the gravity dual media filters.

The Dual Media Filters shall be installed within a fully covered building with RCC roof.

The filter should be designed to ensure that filtration run time is not less than 24h in worst water condition and at maximum plant output capacity. Each filter bed shall be capable of being isolated and taken out of service, i.e. for maintenance while adjacent beds are still in operation.

In each plant stream, when one filter is under backwash operation, the remaining filters shall be able to handle the filtered water flow required for all the RO trains in operation.

Granular media filtration system will consist of about 80 individual filters (40 filters for each plant stream) that will operate in parallel. Each filter inlet shall include an isolation valve/gate, and in filtering mode, the feed water shall be fed into the filter, above the filter media, in such a manner so as the filter media is not disturbed. The water shall flow through the filter media, through filter floor nozzles, and into a chamber underneath the filter floor. The filter design shall be as per standard media filter design.

Filtered water shall flow from the filtrate collection chamber, through a flow control into the RO feed tank. The maximum size of an individual filter shall be within 12.5 MLD based on a successfully proven design and operating plants.

When in backwash mode, water from the backwash tank shall be pumped by dedicated duty/ standby backwash pumps, through control and isolation valves into a single filter filtrate chamber. The backwash water shall flow up through the filter media support, up through the filter media, removing filtered solids from the filter bed, and into the backwash water troughs, running the length of each filter. The backwash water troughs shall be designed to ensure that dirty backwash water is removed evenly from the whole length of the filter. Backwash effluent shall pass from the backwash troughs, through the effluent isolation valve, and to the backwash effluent tank. The system shall ensure that no more than 5% of the top media is lost over a period of one year, and this shall be tested during the performance test. Pre-Treated/Filtered Sea Water shall be used for backwashing the media filters. The water shall be withdrawn from the filtered water tank/RO feed tank. However, the use of RO reject brine may to explored for filter backwash. Suitable pumping machinery with necessary standby shall be provided.

The filter underdrain system shall be of monolithic reinforced concrete slab, or SS plates supported on concrete dwarf walls and be designed to tolerate all loads imposed during installation and during operation. The means of collecting filtrate and distributing air shall be by use of nozzles set in the reinforced concrete floor. Nozzles with fine slots shall be used for collecting filtrate and distributing backwash water and air. A uniform distribution of the nozzles of not less than 60 numbers per square metre shall be employed. The nozzles shall be constructed of ABS plastic and have vertical reverse wedge slots to prevent filter media greater than 0.40 mm from passing through and to be self-cleaning in the filtration mode. The design of the under-drain system shall be based on the successfully proven design and operation of the filters.

All necessary equipment for automatic backwash and operation shall be provided. It shall be ensured that the entire backwash is carried out in the proper way to reach the filter washing without operator intervention. Typically, there will be 8 automated valves/gates in each filter – 1 inlet gate, 1 waste outlet gate, 2 filtrate outlet sluice valves, 2 backwash inlet sluice valves and 2 air inlet scour valves for two beds of one filter. In addition to the automated system, the plant shall be provided of a full backup backwash system that can be operated under the guided control of one operator. Backwash system should be designed for the specific media used and for varying flow requirements with the change in water temperature in summer and winter seasons for effective backwash. Air scour system shall be provided for the better efficiency of the backwash. Blowers should have their acoustical protection and should be located inside the building or under a shade. Design should ensure that safe start-up of the blowers can be achieved automatically and should prevent backflow of water into the air system under all conditions.

For each filter, a filter control desk shall be provided for local operation of the filter in manual or automatic modes. This will allow operator selection of the filters to be backwashed and operator selection of the durations of various steps in the backwashing process. The control desks shall be equipped with selector switches for automatic/manual selection, push buttons for manual opening and closing the filter valve actuators, lights for open/close valve indications and PLCs for automatic time-based step operation of filter valve actuators in backwash operation.

The performance standard may be based on the following criteria

- The filtrate should be clear with the turbidity <0.5 NTU all the time
- The filtrate should be free from colour (with 3 or less on the cobalt scale)
- The filter runs should normally be not less than 24 hours with a loss of head not exceeding 2 m.

- For an efficient filter, the wash water consumption should not exceed 3 per cent of the quantity filtered in between washing.

The indicative key design criteria for the DMF is given below in Table-8.

Table 13: Indicative Key Design Criteria for the Gravity Filters

Filter type	Dual media, downflow
Backwash	Air-water
Average filter cell run duration	24hr
Flow distribution to individual cells	Pipe (if a concrete channel is used, the channel depth should be tapered to keep velocity in the distribution channel above 2 m/s at all times)
Filter cell length-to-width ratio	2:1 preferably
Maximum Water depth above filter top	2.5 m (should be equal to or slightly higher than filter bed head loss)
With two filters out of service (N-2) per stream	< 8 $m^3/m^2 \cdot h$
Backwash rate	25-40 $m^3/m^2 \cdot h$ – variable with temp.
Air Scour rate	50-60 $m^3/m^2 \cdot h$
Duration of backwashing (total air plus water)	30 min (includes filter cell draining and fill-up)

Filter Media

Filter media is defined in terms of effective size and uniformity coefficient. Effective size is the sieve opening size in millimetres that permits 10% by weight to pass. The uniformity coefficient (UC) is the ratio between the opening size of the sieve that will pass 60% by weight and the effective size of the medium. The type, uniformity, size, abrasion resistance and depth of filter media are of key importance for the performance of pre-treatment filters.

Anthracite and sand shall be used in the dual media filters. Deep dual-media filters are to be designed to achieve enhanced removal of soluble organics from source water by filtration. Perur site has high seawater TOC. Bidder shall analyse the seawater quality for the design of gravity dual media filters and all other process units in order to achieve the required filtered water quality suitable for feed to SWRO system.

Sand shall be of hard and resistant quartz or quartzite and free of clay, fine particles, soft grains and dirt of every description. It shall be high grade, complying with Sections 1, 2.2 and 5 of the Standard Specifications for Filtering Material (ANSI/AWWA B100-09, AWWA Standard for Granular Filter Material). Sand should be of high quality with ignition loss not to exceed 0.7% by weight. Silica content should not be below 90%, and wearing loss should not exceed 3%. The sand shall be well-graded, and material showing abnormal grading shall be rejected.

The particle size distribution shall be determined by screening through standard series sieves. The per cent size shall be determined from a plot of the percentage of the material passing each sieve, against the rated opening of the sieve. The filter media and underdrain system shall be designed to achieve uniform distribution of both filtrate and backwash water and air.

The indicative media parameters are given in Table 9 below. Bidders are required to fulfil the requirement unless there is sufficient operational evidence to change and which is acceptable to the Engineer.

Table 14: Indicative Media Description for the Gravity Filters

Descriptions	**Units**	**Values**
Top layer		Anthracite
Minimum depth	m	1.2
Effective size	mm	0.6- 0.8
Uniformity coefficient		1.4
Bulk density	ton/m3	0.85
Bottom layer		Silica Sand
Minimum depth	m	1.5
Effective size	mm	0.5-0.6
Uniformity coefficient		1.4
Bulk density	ton/m3	1.8
Specific gravity		2.55-2.65
Below sand layer		Garnet
Depth	m	0.2
Effective size	mm	0.5
Uniformity coefficient		1.4
Bulk density	ton/m3	3.5

Apart from above, the gravel will be used below garnet. Gravel of bigger size will be placed between garnet and the under drainage system to prevent sand from entering the underdrain and to avoid uniform distribution of wash water. The gravel and garnet should accomplish both purposes without being displaced by the rising backwash water. Sizes of the gravel may vary from 50 mm at the bottom to 5 mm at the top with 0.3 m depth. Reference may be accessed to IS 8419 Part (I)-1977 for filter gravel.

The Contractor shall provide a detailed automatic monitoring system in the O&M manuals, to be approved by the Engineer, to ensure reliable control of the performance of the filtration plant. The filter outlet control valve position and head-loss across each individual filter bed shall be continuously monitored from the control room. The flow-rate out of each filter shall also be continuously monitored. The filtered water turbidity and flow rate in filtered water channel leading to RO feed water tank shall be continuously monitored from the control room. The quality of the filtered water from each individual filter shall be routinely monitored by a grab turbidity sample and analysis.

The air scour and backwash flow rates shall be continuously monitored during filter washing. Local indication of each backwash pump discharge pressure shall be provided. Local indication of each air blower discharge pressure shall be provided. Each air blower shall be provided with a high discharge pressure switch. A sample point may be provided on each filter backwash effluent line close to the filter, to enable the duration of the filter backwash to be optimised.

The conductivity and SDI of water in the filter to waste line as a filter is returned to service after a backwash shall be routinely monitored by a grab sample and analysis. The filtrate during the maturation period after backwash is proposed to be recycled to the filter inlet to reduce the per cent waste of filter. An alarm shall be raised in the event of high turbidity in the common filtered water main. Also, an alarm shall be raised in the event of high differential pressure across a single filter.

During filtration mode, the filter outlet valve shall be controlled to maintain a constant level in each filter. The control system shall ensure that in normal filtration mode, the instantaneous outlet flow rate from an individual filter does not vary by more than + 10% from the overall average flow rate of all in service filters even in the event of two filters out of service when the filtration rate will be enhanced to meet the total required filtrate flow rate. This shall be confirmed during the performance test by analysis of the individual filter trends from the DCS/PLC. All filter valves/gates and penstocks shall be fitted with electric actuators with facilities for remote and local manual operation using the local panel to be provided for each filter.

3.4.4.8 *RO Feed Tank*

The filtered water flows to the RO feed tank under gravity. The tank shall be constructed of RCC and equipped with vents. The RO Feed Tank shall be equipped with an overflow line to the Outfall tank or the intake pumping station.

There will be two RO feed tanks – one for each process stream. The capacity of each will be designed for 30 minutes of filtered water flow, i.e. 10000 m^3 each. The RO feed tank will serve as control storage between the filtration system and the RO plant. It will ensure that the flow to the RO trains will be constant while the production from the pre-treatment system fluctuates due to backwashing. To ensure gravity filter backwash water is always available and does not disturb the RO feed flow, the tank design will offer a two-compartment design. The first compartment will feed the second compartment by overflow. The first compartment will serve the backwash requirement and provide a capacity of 2,000 m^3 (backwash requirement for at least 3 filters). The ERD and HP booster pumps will be connected at the outlet of this second compartment that will offer a minimum working capacity of 8,000 m^3 (at least 25 min residence time). The minimum working volume shall be kept between the high-high level and low-low level. The level in the RO feed tank shall be continuously monitored. The tanks should be partitioned in such a way that one half can be isolated for cleaning while another half tank supplying water for backwash and RO feed.

In case of emergency, this first compartment will have a provision to be fed from the outlet of DAF. As the main process flow reservoir, this two-compartment tanks will be constructed in concrete.

3.4.5 Seawater Reverse Osmosis System

The Bidders shall provide a complete SWRO system suitable to produce 404 MLD permeate with plant availability up to 97% of the time in a year. Bidder's offer shall include RO trains, each consisting of:

- Rack/framing, and power and instrumentation cabling and equipment;
- Feed, permeate, brine, cleaning/flushing piping and equipment including the individual suck back tank for each train (skid);
- RO trains required for providing the rated output at the end of the membrane guarantee period.
- The system shall be capable of producing desalinated water on a 24 hour, 7 days a week basis.

The trains shall be sized for a Net potable water production capacity of 400,000 m^3/d of the required product water quality at the worst-case conditions (minimum seawater temperature, maximum seawater salinity, maximum seawater turbidity, fouled membranes, aged membranes), with all membrane trains in service.

The bidder shall provide membrane projections covering the whole range of anticipated seawater quality (especially extremes of temperature and salinity) for new, clean membranes and old, fouled membranes and have to submit along with the bid. In case of failure of submission of same, the bid may be rejected, considering the same as non-responsive.

Each RO train shall incorporate pressure drop and regulation devices in the brine reject line to maintain and control conditions within the trains. It shall be possible to measure the product flow rate and feed - brine pressure drop of each individual RO train.

The SWRO system shall be fully automated with auto-transmission and control of all the required parameters. The bidder shall not propose any experimental features for the RO Plant construction. Only proven and well tested RO configuration shall be used. Bidders shall provide the experiences of the successful implementation and working of the plants with the configuration proposed by them for the 400 MLD SWRO system design.

The Plant shall be flexible to accept & implement the modifications, which may be desirable as a consequence of a rapid technological improvement in RO and its equipment and any changes in feed quality. The Plant shall also have the provision for interchangeability between membranes supplied by various membrane suppliers and incorporate interlocking end caps reducing permeate back pressure drops while providing long term seal integrity. The pressure at membrane inlet shall be designed such that it allows interchangeability of membrane brands and types from different Manufacturers. Furthermore, the Plant shall be designed to be operated with minimum maintenance, requiring minimum operating personnel.

Each train shall have a capacity of 25 MLD and should have its own dedicated RO Booster, ERD Booster, ERD and High-Pressure Pump along with energy recovery system. Stand by train(s) shall be provided to use in case of any train is offline during CIP or for any other maintenance work. The bidder can propose the 3 Centre/ Pressure Center design under a separate alternate quotation. In that case, the bidder is required to provide the experiences of the successful implementation and working of the specific design and also the sufficient technical and economic advantages of the Center designs acceptable to the Engineer.

The high-pressure shall be designed not to introduce flow and/or pressure pulsation in the feed or brine stream. The reverse osmosis system has to be operated with fluctuating feed salinity, and feed temperature and variation in RO permeate recovery. An appropriate regulation of the feed pressure for each reverse osmosis train separately by a corresponding design of the high-pressure pumps and automatic feed pressure control is required.

Each train should include all necessary instrumentation and online monitoring to enable proper operation, early detection of process deviation on the trains, normalization of the trains performances and protection of the unit against the improper operation. The design must include at least instrumentation to measure and display on the HMI system: membranes feed flow, permeate flow, brine flow, ERD feed flow, membranes feed pressure, membranes head losses, membrane brine pressure, feed conductivity, ERD conductivity, permeate conductivity, feedwater temperature.

High-pressure piping and equipment should be designed as per ASME standards. Proper protection against excessive pressure must be provided.

Connection of pressure vessels should be done using Victaulic flexible couplings. Pipe and fittings material including Victaulic couplings for the feed and reject (high-pressure side) shall be suitable for the Seawater and RO brine handling under operating pressures. They shall be in super duplex stainless steel or equivalent with a minimum PREN of ≥42 and CF ≥35. The material of construction and seals for Victaulic couplings shall be suitable for the Seawater and RO brine handling under operating pressures. All castings used for coupling housings, fittings, valve bodies, etc., shall be date stamped for quality assurance and traceability. Couplings shall have a nominal 3:1 Safety Factor over published working pressures. Fittings shall be constructed of super duplex stainless steel material having PREN number equivalent to the pipe system in which it is installed.

Grooved joints shall be installed in accordance with the manufacturer's latest published installation instructions. Grooved ends shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove.

- Gaskets shall be of an elastomer grade suitable for the intended service and shall be moulded and produced by the coupling manufacturer.

- Gaskets must meet potable drinking water standards and be listed by the approving agency. NSF61 approval and listing shall apply as a minimum standard.

- The grooved coupling manufacturer's factory-trained representative shall provide on-site training for the contractor's field personnel in the use of grooving tools and installation of grooved joint products.

3.4.5.1 *Cartridge Filter*

Cartridge filter shall be used for the safety and protection of the RO system and shall not be operated as a pre-treatment stage. Cartridge filters replacement rate shall be guaranteed as per the Data Sheet.

Carbon steel rubber-lined/GRP vessels shall be provided for housing cartridge filters with quick opening hold-down bolts and having sufficient capacity to meet the maximum flow of the plant without exceeding pressure drop limits when fully fouled. The vessel shall be designed in accordance with ASME Codes design of vessels.

The cartridge filter feed head shall be designed such that the pressure drop between the header at the point where flow to an individual filter is taken, and the water in the headspace above the filter media is at least 10 times greater than the maximum pressure drop between the inlet to the header and an individual take-off from the header. The Cartridge Filter assembly line should be equipped with differential pressure gauges with a pressure transmitter and alarm signal capability. Appropriate means for measurements of differential pressure across cartridge filter shall be provided. Each cartridge filter vessel shall include inlet and outlet isolation valves, as well as drain and vent valves. Each cartridge filter inlet shall include an orifice plate to distribute flow evenly between cartridge filters. The filter vessels shall be equipped to allow the safe and efficient replacement of the expendable cartridge. On-line cartridge filter replacement shall be possible without interruption of the plant operation.

Bidder needs to provide two spare cartridge filter vessels for each train so as filter replacement is done without any impact on water production, such that the maximum loading rate is not exceeded when one vessel is out of service. Micron filter sized shall be rated for 5 µm nominal. These filters shall be arranged so that RO train has a filter upstream of the high-pressure pump. Sample points shall be provided on the cartridge filter inlet and outlet headers.

Cartridge elements shall be all polypropylene construction with non-shredding characteristics. The clean cartridge filter unit shall have a maximum differential pressure of 0.035 bar at the rated flow.

For standard size cartridges, a maximum loading of 650 l/hr per 10" round shall be used. For non-standard cartridge sizes, references shall be provided to support the selected loading rate. Bidder may propose standard cartridge filter battery for SWRO Feed & ERD Low-Pressure feed or dedicated cartridge filters for SWRO Feed and ERD Low-Pressure line.

The RO feed must be totally free of residual chlorine to prevent oxidation of the membrane. Anti scalant and sodium bisulphite (SBS) shall be dosed either upstream or downstream of the cartridge filters. Dosing lines shall be provided such that the operator can select where the chemical is to be dosed. Simultaneous dosing to both locations shall not be required. Mixing shall be provided upstream of the cartridge filters by the cartridge filter orifice plates. Mixing arrangements shall be provided downstream of the cartridge filters. A residual chlorine analyzer and ORP meter shall be located downstream of the cartridge filter to control the SBS dosing rate. A provision to dose Biocide shall also be provided to control the biofouling of the RO membrane. All chemical dosing system shall be provided for the best application in the RO system to the satisfaction of the Employer's representative.

3.4.5.2 *RO Membrane*

The reverse osmosis (RO) membrane shall be thin-film composite 8" spiral wound type. 16" spiral wound membranes are not permitted. The membranes shall be produced by a reputable manufacturer that has successfully provided a similar type of membranes in similar Seawater conditions and plants since at least 10 years.

The reverse osmosis elements shall be high rejection; low fouling seawater spiral wound polyamide membrane units proven for the use under similar conditions of seawater supply at Perur site. Thermal excursions outside the operating temperatures occurring during acid cleaning shall not have any adverse effect on the membrane.

RO Recovery rates shall be selected considering the required quality and the reliability of the system; however, the recovery ratio shall in no case be less than 42% and be more than 46%. The RO section shall be designed for an average flux rate not exceeding 13.4 l/m²/h at the maximum RO recovery of 46%.

Sufficient space provisions shall be considered in the design of the RO Trains to accommodate 10% additional pressure vessels for future requirements. The capacity of each rack should be 25 MLD unless there is proven technical and economic advantages for other capacities which may be provided as an alternative.

Scope also includes 5% of the installed membranes as emergency replacement stock, to be supplied and be stocked in the plant with proposer protection during the complete duration of the contract. Spare membrane should be stored as per supplier recommendation to ensure that maximum allowable temperature and other conditions of storage are not exceeded at any time. A dedicated area should be provided in the workshop or at any other convenient location within the plant. The spare membrane storage area has to be equipped with proper air conditioning (A/C). The A/C shall be designed for the allowable range of the temperature for the membranes, even in case of a more prolonged standstill of the RO Plant.

Membrane performances and replacement rate should be guaranteed by membrane supplier for at least 5 years; such guaranty should be confirmed by selected suppliers in writing and should be provided in the bid.

The warranty for the expected lifetime of the RO membrane shall be 7 years (+/- 0.5 year) which shall be provided by the bidders in their bid submission. The used RO membranes shall be sustainable recycle/disposal compliant with Indian laws and regulations. The procedure of recycling/disposal will be reported regularly to CMWSSB.

Plant should be designed to ensure that production and quality can be maintained with at least 3 membrane suppliers without modification of the major equipment. Sufficient sampling points shall be provided to test the product water quality from every RO vessel.

3.4.5.3 *Pressure Vessel*

RO membranes shall be installed in GRP pressure vessels. These modules shall be factory assembled and tested, and supplied mounted on and within robust framing, and shall be suitable for landing into a plinth and ready for pipework connections.

The RO pressure vessels shall be designed and manufactured in accordance with ASME Section X and duly coded and stamped. Each train will have enough space to install enough number of modules to be installed at the end of the guarantee period or 10% free space whichever is greater. There should be a suitable arrangement for the air venting of the pressure vessels. The design of the pressure vessel shall allow interchangeability. The Pressure Vessels may be supplied as either side port side entry Pressure Vessels or multi-port, side entry Pressure Vessels. The Vessel exterior shall have a smooth surface and shall be painted with white polyurethane paint. Paint should have UV resistance properties. Each vessel shall have a resin impregnated identifying number / bar-code.

Each pressure vessel has to be equipped with conveniently accessible sampling points for product water lines. Furthermore, the RO System shall provide a sampling station for each train to take permeate sample from each vessel. Each pressure vessel shall house not more than Eight (8) membranes per vessel. Train should be designed to provide sufficient air venting of the pressure vessels. The vessel interior shall be free of pits or voids that may promote bacterial growth, and the inside of the vessel shall have a smooth and mirrorlike surface to prevent the above.

Tolerance of the pressure vessels should ensure that front port or side port connections are in compliance with Victaulic connection maximum tolerance.

3.4.5.4 *High-Pressure Pump*

High pressure (HP) pumps shall be from a reputable manufacturer who has supplied pumps that have been working satisfactorily for not less than five years. The High-pressure pump can be either designed with Variable Speed Drive (VSD) or with a Fixed Drive, wherein the RO booster pump should be capable of providing feed pressure adjustments suitable to cover the required membrane pressure range up to maximum salinity events. The casing, Impeller and shaft of the HP pump shall be of Super Duplex with minimum PREN$\geq$42.

It should be noted that the correct sizing of the RO pumping system is critical, as under-sizing will not achieve the required permeate flows and over-sizing may require excessive pressure to be burnt-off at the throttling valve. Therefore, it is suggested that bidder take due care and full diligence in designing the system. The Bidder in its bid, need to submit the operational philosophy for the HP pumping system in totality with RO system over the full range of seawater salinity and temperature.

3.4.5.5 *Energy Recovery Device*

Energy in the high-pressure brine from the reverse osmosis membranes shall be recovered only by an isobaric energy recovery device (IERD). The IERD's shall be arranged such that a single unit can be removed from service and at least 95% of the total work exchanger capacity is available whilst the single unit is isolated. Isolation shall be manually performed, either by operator valves or by fitting end caps. IERD should be made of corrosion-resistant material or in a super duplex or super austenitic stainless-steel material with a minimum PREN ≥42.

The Energy recovery system installation shall in no regard cause a constraint to operate, cleaning, maintenance, preservation or mothballing procedures of the reverse osmosis system. The ERD selection shall be with the least maintenance requirement to improve plant availability. The unit shall be mounted on a skid, valve arrangement and control based as the proprietary design. Adequate support for the equipment shall be provided. The proprietary material used in the construction of such energy recovery devices shall be suitable for the seawater condition specified in the tender document.

The recovered high-pressure feed at IERD outlet shall not contain more than 2.5% of the membrane brine by volume. This shall be determined from conductivity measurements.

The proposed Energy Recovery Device(s) shall have a minimum of ten (10) years operating history in seawater applications. The expected lifetime of the Energy Recovery Device(s) shall be at least twenty-five (25) years. Efficiency of a single Energy Recovery Device (per unit) must be over 95% throughout the designed operating range. The sound levels emitted from the device should be at national standards. The Energy Recovery Device(s) must be able to operate within all the parameters of this Specification through the water temperature range and through the ambient air temperature range.

3.4.5.6 *Neutralization*

Neutralization system should be provided to neutralize the CIP solutions before it is discharged to the sea along with the RO brine via the outfall tank. The neutralization system should have a dedicated tank with recirculation /mixing facility and allow for neutralization of the CIP solution in less than 4 hours. Neutralization in the CIP tank is not permitted. There will be two neutralization system (one for each plant stream). The neutralization tank of each stream shall have capacity at least 4 times the CIP tank volume. The pump will run in recirculation mode till neutral pH is observed & then it will go to dumping mode.

No manual intervention should be required from the operator to carry out the neutralization. pH should be monitored before discharge into the outfall tank through online pH analyzer with an interface to the recirculation system. The pump will run in recirculation mode till neutral pH is observed & then the pump will run into dumping mode. The system should have 100% redundant (Stand by) pumps and valves for recirculation/dumping.

All the equipment should be designed to withstand the range for high TDS/salt concentration and high-alkaline /low-acidic pH expected, including pH of cleaning used during high fouling or scaling events. If included in the RO building, the neutralization should be covered, and a vent should allow ventilation of the gas outside of the building at a reasonable distance of any access and walkways.

3.4.5.7 *RO Permeate Tank*

RO permeate tank of minimum 30 minutes of detention shall be provided to store sufficient permeate water for CIP, flushing and service water. The tank can be either in concrete with corrosion-resistant tiling or glass fused stainless steel with proper internal and external protection.

There will be two RO permeate tanks – one in each plant stream of 200 MLD (tanks connected to each other with sufficient isolation valves). To ensure membrane flushing water is always available, the tank design will offer a large capacity of 5000 m3 allowing one skid CIP, all trains flushing and one backwashing of the limestone filter. This tank will serve membrane flushing pumps and a service network providing water to limestone bed backwash, chemical building and RO building (flushing all the seawater pumps at the stoppage, rinsing leaks to avoid corrosion).

3.4.5.8 *Clean In Place System*

At least two clean in place (CIP) system shall be provided – one in each process stream of 200 MLD. The cleaning system should enable cleaning of all plant trains. It should consist of a cleaning tank with the capacity necessary for the preparation of the cleaning solution for one complete train.

The CIP Tank shall be sized for a working volume equivalent to the volume of the maximum number of pressure vessels to be cleaned at any one time, plus the volume of the maximum length of CIP pipework in the feed, concentrate and permeate header systems with 20% safety margins.

CIP tank the volume of the tank should be at least

$$V_{\text{CIP tank}} = V_{\text{skid}} + V_{\text{piping}} + V_{\text{minimum suction level for pumps}} + 20\% \text{ safety margin}$$

- CIP pump design to ensure sufficient flow for the membrane cleaning minimum of 9 m3/h per pressure vessel
- CIP Cartridge filter
- Heater design for the minimum seawater temperature (temperature of the CIP solution should be monitored)
- Chemical injection and pH control
- Recirculation loop for CIP preparation and chemical dilution

Permeate from the permeate tank shall be used to fill the CIP Tank. The CIP Tank fill line inlet shall be above the CIP tank overflow and shall include a non-return valve, to ensure that there is no risk of backflow of chemicals into the permeate tank.

The location of the CIP Pump discharge back into the CIP Tank and the CIP pump suction line shall be carefully designed to ensure that when in recycle mode, the contents of the CIP Tank are well mixed. The CIP pump suction line shall also be designed so that air is not entrained into the CIP Pump, even when the tank is running in recycle mode at a low level. The bidder shall calculate the increase in temperature of the water in the CIP tank due to the heating action of the CIP pumps, either in recycle mode or cleaning mode, as well as the heat of solution of the cleaning chemicals. If the temperature of the contents can rise above 45°C in normal operation, with the warmest expected seawater temperature, then facilities shall be provided to cool the CIP Tank contents. It is anticipated that this shall be achieved by a heat exchanger on the CIP Pump discharge recycle line, cooled by a suitable stream of process water.

In cleaning mode, the water pumped by the CIP pumps shall pass through nominal 5 µm cartridge filters. The design of the cartridge filters shall be as provided in the RO system, except that no excess capacity is required.

Each RO train stage concentrate header shall be connected to the CIP system concentrate header, separated by a suitable isolation valve. The CIP system concentrate header shall return cleaning fluid into the Neutralisation Tank. In cleaning mode, the RO train concentrate header shall be isolated from its energy recovery device by a suitable isolation valve.

Each RO train stage permeate header shall be connected to the CIP system permeate header, separated by a suitable isolation valve.

The CIP Tank shall be fitted with a drain flush with the tank floor. The drain shall be connected, via an easy to operate isolation valve, to the Neutralisation Tank.

3.4.5.9 *Flushing Unit*

RO train should be automatically flushed after the stop, and the flushing should include HP pump, RO train, ERD and recirculation pump. Flushing water storage (Permeate Tank) should allow to flushing of all the plant trains in one plant stream of 200 MLD while the plant is not producing water. The permeate tanks of both the plant streams shall be interconnected with sluice isolation valves to allow additional permeate water as needed for train flushing.

The flushing system must be independent of the cleaning system to allow flushing and cleaning operation at the same time. Flushing pump, pipings and necessary valves on the train must allow flushing of all the plant trains during an electrical outage. A standby pump should be provided to ensure availability of the flushing system.

A diesel set of suitable capacity shall be provided to run the RO flushing system and to flush the RO trains in case of power failure.

3.4.5.10 *Membrane Skid Test Unit*

A membrane skid test unit must be provided to enable during operation the test of the individual membrane. Skid test unit should enable to preform test as per ASTM D 4194 standard. The membrane skid test unit should be feed by pretreated water.

It should include cartridge filter, HP pump, single membrane testing unit and all necessary equipment for flows control and sampling points. Pretreated water tank may be used to prepare cleaning for cleaning test on individual membranes.

3.4.6 **Chemical Storage System**

There will be a separate chemical building area for Pre-treatment, RO system and Post-treatment for each 200 MLD plant streams. The building area shall be designed to receive and store all of the bulk chemicals safely and to meet the specified performance and technical criteria. Bulk chemicals are to be stored in well-designed chemical storage tanks and bunded areas.

3.4.6.1 *Design Criteria*

The design intent is to ensure safe unloading of chemicals, no losses of containment, and safe operation of the storage. Therefore, the storage area will be:

- Engineered to high standards
- Safe for operators and the environment
- Durable and maintainable
- Compliant with statutory regulations

Chemical area layout will allow sufficient margin between refill points and empty tanks. Control systems will ensure that the tanks do not overflow while filling. Chemical fuming shall be dealt with systems in place to manage fuming. Any heating requirement shall be provided as appropriate to avoid freezing of chemicals such as sodium hydroxide.

All piping and equipment should be suitable for transported chemicals. Chemical pipes should be housed in a trench. Piping of incompatible chemicals should be separated.

Local visual indication of the contents of all storage tanks shall be provided along with level sensors and transmitters. For liquid storage tanks, magnetically coupled type instruments shall be used.

Tank Capacity/Delivery Size

All chemical storage facilities shall be suitable for 30 days of chemicals availability at RO Plant Site. The Long lead chemical shall be provided with 40 days of storage facilities. For Sodium Hypochlorite combined storage & dosing shouldn't exceed 14 days, due to its low shelf life.

Where possible, tanks are sized to allow for bulk 20-tonne deliveries. The minimum time between two deliveries for all chemicals except sodium hypochlorite. Bulk storage has not been allowed for thickening and dewatering polymers which will be delivered in 1,000 L IBCs and stored and dosed from the dewatering building.

For bulk deliveries (1000 litre IBC and above), the delivery vehicle shall include a compressor such that chemical can be delivered to the storage tank without external pumping. The Contractor shall ensure that the design of the reception and storage facilities meets the standard requirements of the chemical delivery.

Unloading areas will be provided sufficient for the movement of road trucks. Unloading areas will be paved and sloped to a drain capable of collecting any spillage, and with a capacity of 9,000 L or the capacity of the largest tank vehicle compartment.

Tank Bunds

Storage tanks should be held in a bund to ensure that, in case of chemical spillage, chemicals are retained. Bund capacity should be at least 110% of the biggest tank or 50% of the total tank capacity whichever is the biggest. Bund should be free from cables, instruments and as far as possible free of piping.

Bund areas will be based on a bund wall height of 1.0 m and the capacity of the bund with this wall height is 100% of the total volume of the tank leaving 1 ft of freeboard. No allowances were made for sumps or the fact that the effective volumes of the tanks will be less than the total.

Because most of the materials that are being stored are Class 8 corrosives, consideration will be given to linings in the concrete bunds, as any spills will attack the concrete. In general, the bunds are lined with acid/alkali-resistant epoxy coatings. In addition, bund perimeter walls must be impervious to the chemical being stored; therefore, the lining of these walls must be considered as well.

Minimum Separation Distances

The information on minimum separation distances is presented below.

- Between tanks: 0.6 m
- Between a tanker connection point and protected works: 5 m
- Between a tank (3,000 to 50,000 L) and protected works: 5 m
- Between a tank (> 50,000 L) and protected works: 8 m
- Between a bund wall and protected works (from inside the bund wall): 3 m

Segregation

Tanks containing chemicals that react dangerously must be kept in separate bunds and segregated by a suitable distance. Therefore, the bulk chemical storages shall be grouped together and segregated accordingly as the per the appropriate British or Indian Standard.

Construction Material

All bulk storage tanks will be manufactured from RCC building with corrosion-resistant tiling or glass/fibre-reinforced plastic (GRP/FRP). A plastic liner such as PVC or polypropylene will be used. Plastic liners need to be stress relieved prior to use. The sodium hydroxide bulk tank will be manufactured from carbon steel or other suitable material.

Liquid Chemical Transfer

The delivery vehicle/isotainer will supply its own electric transfer pump. A suitable power point shall be provided at the unloading area for the pump. The delivery tankers will have a flexible hose and coupling to connect with the storage tanks fixed transfer pipe.

Level Indication

Each tank shall be supplied with a level transmitter and independent low- and high-level switches. There will be a level indication display visible from the vehicle unloading point during discharge. An independent high-level alarm/switch will be provided in the tank that will be interlocked with the power supply for the delivery tanker. This alarm and switch, which will be below the overflow level, will be activated when the high level is reached. It will also stop power to the GPO, into which the tanker's transfer pump is connected. The contents of all storage tanks shall be continuously monitored on the HMI.

Chemical Area Safety

The design of all chemical storage and dosing systems shall take into account all international standards and safety requirements, and shall ensure the safe reception, transfer and dosing of chemicals. As a minimum, the following safety features shall be included:

a. Chemical delivery, transfer, storage and dosing shall be carried out in bunded areas. Bunds shall be sized to retain at least the contents of the largest storage tank +10%.

b. All bunds shall include provisions for the safe removal and disposal of any spilt chemical, as well as accumulated rainwater, by the use of portable sump pumps.

c. There shall not be a direct connection from bunds to surface drain.

d. Common bunding of two or more chemicals which might result in an un-safe chemical reaction, were these chemicals to mix, shall not be permitted. Dosing lines shall be sleeved in critical areas.

e. Tanker delivery connectors shall be unique to each individual chemical, in order to avoid delivery to the wrong vessel.

f. A sufficient number of safety showers and eyebaths shall be provided to allow rapid access from all chemical storage and dosing areas.

g. All confined areas which could potentially be exposed to a toxic gas shall be equipped with a source of safe air, fit for human consumption, for use in the event of a leak.

h. All chemical storage tanks shall be vented externally.

3.4.7 **Chemical Dosing System**

Facilities shall be provided for the delivery, storage and controlled dosing of all necessary process chemicals separately for both the plant streams.

Dosing systems shall include all the necessary equipment to ensure controlled delivery of the chemical at the required flow rate, irrespective of variations in chemical feed tank level, or delivery point pressure (e.g. pressure sustaining valves at the dosing point).

Chemical dosing system should be designed to allow safe and reliable operation. All chemical storage and dosing should be clearly identified; chemical piping should be colour-coded.

Each dosing line shall be provided with an isolation valve and a non-return valve as close to the point of injection as possible.

Chemical systems shall be designed to ensure that there is no circumstance in which a dosing pump can generate a pressure which exceeds the design pressure of any part of the system downstream of the pump. All the necessary equipment to protect dosing pumps from unwanted particulate material present in the chemical delivery shall be provided.

All materials shall be compatible with the chemical being used. Standby equipment shall be provided for all dosing pumps. All metering pumps shall be N+2 spared (1 installed and one warehouse spare) and comply with API 675 standards. Stand-by should start automatically without operator manual operation. All the metering pumps considered should be of a similar type as much as possible. The pumps shall be mechanically coupled Diaphragm type metering pumps. These pumps are to include inlet & outlet valves, check valves, discharge relief valves, reciprocating mechanism, gear reducer, coupling and all necessary instruments and drivers, all assembled, aligned and mounted on a standard base plate, ready for installation. Pulsation dampeners shall be provided on the individual dosing pump. All pumps shall be supplied with flow switches or flow detection devices integral with the pump.

All dosing lines and pumps shall be provided with facilities to enable the flushing of pumps and dosing lines with boosted service water. The drain lines shall be provided to drain the suction and discharge pipes of each dosing pump after flushing.

Chemical dosing pump suction should be equipped with filters and isolation valves to allow online filter maintenance. A standby filter must be provided on the shelf to enable proper maintenance while dosing system is in operation.

Chemical dosing rate should be paced with plant feed flow rate and seawater parameters such as turbidity, TSS, pH and organics. A calibration chart based on each quality parameter should be available on the HMI for auto-selection of the most optimum chemical dose rate with change in seawater quality parameters. Flowmeter should be installed on each chemical dosing line. Value should be available on the HMI systems. Chemical pumps suction and discharge pressure should be monitored.

If chemical dilution is required automatic (such as a polymer), safety should be provided to ensure that dilution is in operation during dosage. Stand-by dilution system should be provided.

The flow rate of ferric chloride coagulant, flocculation aid polyelectrolyte, RO anti-scalant and other essential chemicals shall be continuously monitored on the HMI systems. These flow meters may be used to generate the low flow signal and auto-switch to the standby pump. It shall be possible to remove the flow meter for maintenance whilst still keeping the system in operation.

All chemical solution preparation and dosing tanks shall be kept inside the chemical building with proper ventilation. There should be the mechanical lifting of the chemical for solution preparation. The tanks shall be filled automatically with service water for dilution using level transmitters and solenoid valves at the service water inlet pipe.

Agitators shall be provided in each tank of appropriate size and specification as needed for the solutions which require constant stirring.

3.4.7.1 *Sodium Hypochlorite*

Sodium hypochlorite shall be dosed intermittently to the intake header for shock chlorination and continuously at the intake pump discharge to eliminate micro-organism and control bio-fouling in the downstream processes. Only one sodium hypochlorite storage and dosing system shall be provided for shock chlorination.

The chemical shall be delivered in liquid form, in drums, and stored in a dedicated drum storage area, with environmental protection to prevent either deterioration in the quality of the chemical or harmful consequences to the operator or environment. The drums shall be stored below 40°C and protected from light. Drums shall be kept in an industrial shed with proper ventilation and environment control.

The chemical shall be transferred from drums to the hypochlorite storage tanks. A minimum of two hypochlorite storage tanks shall be provided. All facilities shall be provided to enable the operator to transfer the chemical effectively and safely. Any pumps and/or blowers for chemical transfer shall be equipped with a standby unit.

The liquid chemical shall be dosed to each dosing point, in a controlled manner, by dedicated, duty/standby sodium hypochlorite dosing pumps.

The storage tanks shall be connected to the dosing pumps by a common header. The elevation of the dosing pump shall be below the lowest working liquid level in the storage tanks. The connection from the header to the dosing pumps shall be taken off the bottom of the header. The connection between the header and the dosing pump shall be kept as short as practical, and shall preferably be straight down (via isolation valve) onto the pump suction. A vent pipe shall be provided on the top of the header in the immediate vicinity of the feed to each dosing pump. Each vent pipe shall vent back into a hypochlorite storage tank. This arrangement is required because hypochlorite solution tends to generate gas, particularly in warm conditions, which results in dosing pumps losing their prime.

Table-10 below specifies the physical properties for sodium hypochlorite.

Table 15: Physical Properties of Sodium Hypochlorite

Sodium hypochlorite	NaOCI
Physical form	Clear, yellow-green liquid
Active component	Cl_2
Bulk density (kg/m3)	1170
Liquid viscosity (kg/ms)	~ 0.002 (depending on temperature)
Active conc. of delivered product (% w/w as Cl2)	10%-12.5%

Each hypochlorite storage tank shall be sized to retain a minimum volume equivalent to the greater of:

a) 48 hours of hypochlorite solution for intake at maximum flowrate and average dose

b) the maximum quantity of intake shock chlorine required in a single shock chlorination event.

3.4.7.2 *Sulphuric Acid*

- Sulphuric acid shall be dosed upstream of the Lamella Settler for coagulation pH and scale control.
- The chemical shall be delivered in liquid form and stored in dedicated storage tanks.

- The liquid chemical shall be dosed to each dosing point, in a controlled manner, by dedicated, duty/standby sulphuric acid dosing pumps.
- Undiluted chemical shall always be within a bonded & screened area, or in dual containment pipework, with leaks flowing to containment areas.
- The system shall be designed to ensure that water cannot flow back up into the concentrated acid pipework.

Table-11 below specifies the physical properties for Sulphuric Acid.

Table 16: Physical Properties of Sulphuric Acid

Sulphuric Acid	H_2SO_4
Physical Form	Clear liquid
Active Component	H_2SO_4
Bulk Density (kg/m^3)	1840
Active Conc. of the delivered product (% w/w as H_2SO_4)	96 to 98%

The exterior of the tank shall be coated as follows:

- One coat of a two-pack zinc-rich epoxy primer applied to a minimum dry film thickness of 50 microns;
- One coat of a high build polyamide cured epoxy applied to a minimum dry film thickness of 150 microns;
- One coat of a re-coatable polyurethane applied to a minimum dry film thickness of 50 microns.
- The tank shall have a desiccator arrangement of the ventilation pipe to prevent moisture from entering the tank. All the outlet nozzles shall have double isolation valves.

The acid tank shall be installed in separate dykes. Each dyke volume shall be capable of holding the gross tank storage volume including board for the free area. The dyke area shall be provided with adequate drainage arrangement. The preferred material of construction for bulk storage of sulphuric acid is Carbon Steel with proper corrosion-resistant internal and external coating.

3.4.7.3 *Ferric Chloride*

Ferric chloride shall be dosed upstream of the Lamella Settler for coagulation, and also provision shall be kept to dose before DAF as needed.

There shall be three solution preparation & dosing tanks for ferric chloride and three tanks for polyelectrolyte - each of capacity more than 8 hours of maximum chemical dosing. All tanks and chemical storage area shall be housed in a concrete building with an RCC service water tank at the top of the building for chemical preparation. There shall be two standby (1 installed and 1 in-store) chemical dosing pumps both for coagulation and flocculation chemicals connected to common header. All pumps, pipes and fittings shall be provided similar to other chemical dosing systems and the satisfaction of the Employer.

Table-12 below specifies the physical properties for Ferric Chloride.

Table 17: Physical Properties of Ferric Chloride

Ferric Chloride	$FeCl_3$
Physical form	Clear Dark Red/ Brown Liquid
Active component	Fe^{3+}
Bulk density (kg/m^3)	1420 to 1460
Viscosity (kg/ms)	Approx. 0.0121
Active Conc. of delivered product (% w/w as $FeCl_3$)	40-42.5%

3.4.7.4 *Polyelectrolyte*

Polyelectrolyte shall be dosed upstream of the Lamella Settler and also before DAF if required. The polymer dosed shall be approved for use by the manufacturers for RO membranes.

The strength of solution prepared shall be fully adjustable within the range 0.05% w/w to 0.2% w/w.

The polymer solution shall be dosed from the dosing tanks to the dosing point, in a controlled manner, by dedicated polyelectrolyte dosing pumps. The polyelectrolyte shall be dosed into a carrier water stream, to provide a dilution ratio of at least 5:1 or diluted polymer concentration <0.02. There should not be any fish eye polymer floating in the flocculation tank.

All polyelectrolyte preparation and dosing equipment shall be provided with 100% installed standby.

For sizing the dosing pumps, it may be assumed that the maximum batch strength of polyelectrolyte (0.2% w/w) is used with the maximum dose and that the minimum batch strength (0.05% W/W) is used with the minimum dose. The tank sizing shall also be done based on the maximum dose rate.

The polyelectrolyte dosing tanks (3 tanks) shall be sized to provide at least 8 hours supply under maximum dosing and maximum flow conditions.

3.4.7.5 *Sodium Metabisulphite*

Sodium bisulphite (SBS) ($NaHSO_3$) will be prepared by dissolving sodium metabisulphite (SMBS) ($Na_2S_2O_5$) in water. Dosing of bisulphite is required to remove residual chlorine from the system resulting from intake dosing. Bisulphite may also be used for the RO CIP process and also for RO membrane flushing for storing more than a day.

Sodium metabisulphite shall be dosed upstream of the cartridge filters to allow proper mixing and elimination of the residual chlorine.

The chemical shall be delivered and stored in powder form, in bags. The powder shall be batched up in dilution tanks to prepare a liquid solution for dosing. A minimum of two dilution tanks shall be provided. The tanks and chemical storage shall be housed in the RO chemical building. When a batch needs to be prepared, powder shall be transferred from bags to a discharge hopper. The discharge hopper shall be provided with a sealed lid, which is removed when the hopper is being filled. The powder shall be discharged from the hopper to either of the dilution tanks via a manually operated isolation valve. The dilution tanks shall be covered, and vented to atmosphere outside the chemical building (toxic sulphur dioxide is released when sodium metabisulphite is mixed with water). The dilution tank shall be provided with an overflow which overflows via a water bath within the bunded area of the tank.

Each dilution tank shall be connected to the dosing pump suction manifold via an automatically controlled isolation valve. The liquid solution shall be dosed to each dosing point, in a controlled manner, by dedicated, duty/standby metabisulphite dosing pumps.

Table-13 below specifies the physical properties for Sodium Metabisulphite.

Table 18: Physical Properties of Sodium Metabisuphite

Sodium Metabisulphite	$Na_2S_2O_5$
Physical form	White to off-white, crystalline Powder
Active component	$Na_2S_2O_5$
Bulk density (kg/m^3)	1000 to 1150
Viscosity (kg/ms)	-
Active Conc. of the delivered product (% w/w)	100%

3.4.7.6 *Antiscalant*

Non-polymer based antiscalant shall be dosed upstream of the cartridge filters. The chemical shall be delivered in liquid form and stored in dedicated storage tanks.

The liquid chemical shall be dosed to the upstream of cartridge filter dosing point, in a controlled manner, by dedicated, duty/standby antiscalant dosing pumps.

The table below specifies typical physical properties for an acceptable antiscalant. Details of the selected product are to be obtained from the selected chemical supplier.

Table 19: Physical Properties of Antiscalant

Antiscalant	
Physical form	Clear Yellow Liquid
Active component	Product as supplied
Bulk density (kg/m^3)	~ 1- 1300
Viscosity (kg/ms)	-

Active Conc. of the delivered product (% w/w)	100%

Dosing tank of polypropylene or GRP construction. Each tank shall have a cover with charging port, level switches, makeup water pipe connection and a drain with isolating diaphragm valves; the pipework and valves in uPVC Class 15/PN 16; the antiscalant tank shall be installed in separate dykes. Each dyke volume shall be capable of holding the gross tank storage volume including board for the free area. The dykes area shall be provided with adequate drainage arrangement. The dyke area shall also be equipped with eyewash and safety shower at a strategic location. The antiscalant dosing plant shall be installed on a concrete plinth in the RO building as approved by the Engineer.

3.4.7.7 *Biocide*

Non-polymer-based biocide storage and dosing system shall be provided to combat the propensity of bacterial infection of the RO membrane. The chemical shall be dose as and when required to prevent biological growth in the RO system. The chemical shall be delivered in liquid form and stored in dedicated storage tanks.

The liquid chemical shall be dosed to the upstream of cartridge filter dosing point, in a controlled manner, by dedicated, duty/standby biocide dosing pumps.

3.4.8 **Post Treatment System**

The permeate from the RO plant will be treated in the remineralization/ potabilization plant followed by disinfection and pH adjustment. There will be a separate post-treatment system for each plant stream of 200 MLD capacity. The limestone-based potabilization system shall be adopted considering the plant operation and maintenance aspects.

The post-treatment process shall be complete comprising the following stages:

- CO_2 storage and injection system;
- Limestone filter beds;
- pH correction system including an arrangement for pH booster, if required;
- Corrosion inhibitor dosing;
- Potable water disinfection by chlorination.

All necessary pumps, compressors, equipment, controls and pipework systems shall be included. The CO_2 for the potabilization plant shall be produced by onsite CO_2 generation plant. The onsite CO_2 generation system shall also be facilitated with the provision for the use of liquid CO_2 supplied from external sources.

3.4.8.1 *Onsite CO_2 Generation Plant*

The CO_2 shall be produced on-site and stored, as a liquid, in dedicated storage tanks. A minimum of two storage tanks shall be provided with each to be sized for adequate storage capacity (minimum 15 days storage) shall be provided. Tanks shall be of vacuum-sealed double-walled type. The storage tanks shall be fabricated from ASTM Gr 515/516 plates or equivalent plates as per ASME section VIII Div I or equivalent international standards.

The CO_2 generation system shall include but not be limited to the following:

- Carbon dioxide storage tanks;
- Ambient vaporizers;
- Required pipework, control valves, relief valves, other valves, controls, ejectors etc. required to make it a complete system;
- Motive water pumps and pipework.

Liquid carbon dioxide draw-off system

Carbon dioxide shall be drawn off as a liquid. The outlet pipe of each storage tank shall be provided with a power-operated valve and a guard valve and shall be manifolded downstream. Power-operated isolating valves on the storage tank outlets shall be arranged to fail-safe in the closed position in the event of a power supply failure. The liquid carbon dioxide pipework shall be protected by pressure relief valves and shall be thermally insulated.

Vaporizers

Adequate number of ambient carbon dioxide vaporizers (duty/standby mode) shall be provided and installed close to the storage tank so that the length of liquid pipework is kept to a minimum. The capacity of each vaporiser shall be adequate to meet the maximum dosing requirement continuously. Vaporisers shall be designed for continuous operation at the maximum carbon dioxide demand. Vaporisers shall be provided with power-operated outlet valves to allow for automatic timed changeover of the vaporisers from the duty to standby. Each vaporiser shall be fitted with a pressure relief valve, inlet and outlet pressure monitors and a shut-off valve. The vaporizers shall be fabricated from ASTM Gr 515/516 plates or equivalent plates as per ASME Section VIII Div I or equivalent international standards.

Pressure reducing valve station

Vaporizer outlets shall be manifolded and shall be provided with one duty, one standby single or dual pressure reducing valve and particle filter assemblies. Each assembly shall be provided complete with inlet and outlet isolating valves, filter differential pressure monitor for the particle filter, pressure relief valve and outlet pressure monitor and pressure gauge.

Carbon dioxide dosing

Carbon dioxide gas shall be mixed by a side-stream static mixer and dosed as a solution. Dosing shall be regulated by a power-operated flow control valve. The dosing system shall consist of the pneumatically operated flow regulating, a flow monitor, a pressure monitor, a pressure gauge and motorised inlet and outlet valves and guard valves. The dosing control system shall be provided with a manual bypass.

Carbon dioxide dosing shall be controlled proportional to the post-treatment feed flow and based on an operator set dosing rate.

Each dosing system shall be provided with a static mixer of stainless-steel construction, with motive water provided by the motive water pumps. Water supply to each static mixer shall be regulated by control valve station. The gas supply to the static mixer shall also be provided with non-return and isolating valves.

All the pipework complete with valves, fittings, supports etc. for the total carbon dioxide plant shall be provided under this Contract. This shall include all the pipework from the storage tanks to the dosing point.

All the pipework, valves and fittings shall be in carbon steel. Internals of the valves shall be in stainless steel. Pipe connections of 2 inches and below shall be socket welded. However, the Pipe connection above 2 inches shall be flanged.

3.4.8.2 *Limestone Filter*

The remineralisation plant shall be capable of converting 100% of the permeate from the RO Plant into potable water to the required Drinking Water standard. The potabilization shall be done using CO_2 gas injection and limestone filters. In case of partial remineralization and then mixing of two streams, about 50% of the permeate flow should pass through the limestone filter for remineralization. The bypass stream must mix with remineralized stream thoroughly before transfer to the Potable Water Tanks. The composition of the potable water following remineralisation shall meet the requirements stated in IS 10500.

The required alkalinity and hardness shall be maintained in the product water during remineralization. Finally, the pH correction shall be done through caustic injection to ensure the positive LSI of the product water. The process design of the remineralization plant is given below in Table 15.

Table 20: Indicative Process Design Criteria for Remineralization System

Item	**Requirement**
Limestone Filter Plant	2 plants – 1 for each plant stream
Remineralization Process	Limestone filtration /Carbon dioxide Dosing – 2
Target filter surface loading	10 $m^3/m^2.h$
No. of filter modules per stream	14
Media Contact time	25-30 min
Hardness in the product water	≥ 80 mg/l as $CaCO_3$
Target pH range	7.5 to 8.5
Target Langelier Index	Positive
Max. TDS in product water	450 mg/l (target <500 mg/l at consumer end)

Limestone Filter Beds

Limestone filters should include an automatic backwash system and loading system. Backwash should include air and water step for proper cleaning of the filters.

Proper corrosion protection should be implemented depending on filter material to ensure that corrosion will not impact post-treatment availability and operability.

Limestone grain size should be 2 – 4 mm.

The limestone used should be compatible with potable water application; this should be validated by a certificate from a reputable international lab.

Storage capacity should be at least two months at full capacity.

The Contractor shall be responsible for ensuring purity and local availability of the limestone for design; however, the design should not consider purity above 96%.

Care must be taken that volatile organic and inorganic constituents (THM etc.) cannot be passed to the drinking water. Adequate adsorption and cleaning facilities (absorbers etc.) shall be installed in the CO_2 feed lines to the alkalinisation stage. The use of seawater for remineralisation is not permitted.

The excess CO_2 from the process after the treatment shall be vented out through the degassers or alternatively neutralised by the addition of chemical (NaOH). The degasser tower and the water storage tank shall be fabricated in GRP. In order to control the remineralisation process and to guarantee the quality control of the water the following measurements and control are required;

- Calcium monitoring and control;
- Conductivity measurement;
- Turbidity measurement;
- Residual chlorine detection and control system.

Carbon dioxide gas flow for re-injection shall be automatically adjusted pro-rata to permeate flow with the remote manual trimming to compensate for variations arising from product water temperature and chemical composition. The calcium alkalinity adjustment system shall be automatically controlled to maintain a positive Saturation Index to DIN 38404-10 and calcium concentration.

The piping material for the entire remineralization Plant shall be in GRP. The GRP pipes shall be designed for the maximum pressure that is likely to occur in the piping system (pressure surge phenomena shall also be considered for this purpose). However, the minimum stiffness class of the piping shall be 5000 PSI.

All the valves used for this plant shall be suitable for potable water application. The Valve casings shall be in Ductile Iron or Cast Steel material. Valve internals shall be lined with fusion bonded epoxy coating. Valve discs shall either be fusion bonded epoxy coated or encapsulated with EPDM. Stainless steel shafts shall be provided for the valves.

All the pumps in the system shall be in stainless steel SS316L construction, i.e. casing, impeller, shaft, shaft sleeve, wear rings and other wetted parts. The pumps shall be designed, manufactured and tested according to the latest ISO, BS or DIN or equivalent International codes. Adequate stand by equipment shall be provided in the process. All the standby pumps shall be capable of operating automatically in case of failure of the main pump.

3.4.9 **Product Water Disinfection**

Bidders shall consider the use of sodium hypochlorite for disinfection of product water. Suitable number of N+2 dosing pumps with solution tanks shall be kept to dose in the product water feed to Product Water Tank. The specification for sodium hypochlorite shall be as per the above chlorination description.

3.4.9.1 *Chlorine Residual Monitors*

One chlorine residual monitor shall be provided in each pipeline from Potable Water Tanks to Clear Water Tank for monitoring the final water downstream of the chlorine injection points. The Contractor needs to maintain 0.5 ppm residual chlorine at the outlet of the plant.

The monitor installation shall be located in a covered location easily accessible for viewing and maintenance and shall be provided complete with sample pumps as necessary to ensure the continuity of the sample.

The sampling pipework complete with isolation valves etc. shall be designed to ensure the sample reaches the monitor in a time not greater than 1 minute. The monitor drainage pipework shall permit the visual checking of the presence of flow and shall discharge to the plant drain. Sample water not passed through the monitor shall be returned to the process. The residual signals shall be displayed at the local control panel and the central HMI. High and low chlorine residual levels shall raise alarms at the local control panel and the central HMI.

3.4.9.2 *Ventilation System*

Each area where hypo is stored or used liquid shall be provided with a forced ventilation system. Air intakes shall be sized to allow uniform ventilation and positioned to prevent possible recirculation. Extract air shall be ducted from low level and discharged at a high level.

The ventilation systems shall be designed to provide for general day to day use an air change rate of four per hour and a minimum of twenty changes of air per hour for use in the event that a chlorine leak is detected. Extract fans shall be heavy-duty industrial pattern manufactured from chlorine resistant materials.

Ductwork shall be manufactured from U-PVC extruded sheets or circular sections complying with BS 3757 and BS 3506. Fan controls shall be linked to the gas leak detection system. Hardwired fan controls shall be provided and shall be manually controlled. An override shall be provided to operate the fans as required in the event of a chlorine leak alarm. Fan controls shall be grouped in an enclosure outside the ventilated area and shall include the following:

- fan off/on;
- fan running/failed indication lights;
- low and high gas leakage indication alarm light.

An override facility shall be provided to permit, under manual supervision only, the ventilation fans to be operated in order to disperse gas after isolation of a gas leak. Indicator lights shall be provided at the entrances to the chlorination room and the drum room to indicate whether the ventilation system running.

3.4.10 Product Water Tank (PWT)

Two product water tanks – one for each plant streams, shall be provided by the Contractor with 2-hour storage capacity. The capacity of each product water tank shall not be less than 15ML. The tank shall be subdivided into two compartments so that one compartment can be taken out of service for maintenance or cleaning without disrupting the operation, i.e. water production and distribution. All valves, gates, pipes and instrumentation shall be provided to make a complete water storage tank. The tank will have level sensors and overflow pipeline to the Outfall tank.

The product water from two product water tanks shall be fed to a Clear Water Reservoir (CWR) for pumping water to Porur for distribution.

The main outlet pipe from two product water tanks to CWR will have two metering system, online turbidity, conductively meters and sampling points to demonstrate the product water quality/quantity and to meet the product water guarantee conditions.

There will be provisions for pumping of the product water from PWTs to meet the plant potable water requirements for administrative building, toilets, safety showers etc. and also for a fire system (pumps, diesel set, network).

These two-compartment tanks will be constructed of concrete or metal panels with provision of corrosion protection. The remineralised water from the limestone filter will gravitate to the potable water tank.

3.4.11 Clear Water Reservoir (CWR)

A clear water reservoir shall be provided by the Contractor with a minimum of 30 minutes of storage capacity. The reservoir capacity shall be at least 9000 m3 and made of reinforced concrete. The tank shall be subdivided into two compartments so that one compartment can be taken out of service for maintenance or cleaning without disrupting the water production and distribution. The CWR will be battery limit of the contract.

The Contractor shall provide all sensors, instruments, gates, suction pipe and isolation valve at 5 meters out of CWR. The centrifugal pumps at CWR to transfer potable water to Porur are not in the project scope for the Contractor to provide.

3.4.12 Plant Sludge Treatment System

A sludge treatment facility shall be constructed to treat sludge from the proposed 400 MLD SWRO desalination plant.

The selected sludge treatment units are sludge balance tank (SBT), thickener and belt filter press (BFP). All the sludge will be collected in the sludge balance tank and mixed for a homogeneous sludge solution. From SBT, the sludge will be pumped to the thickener where it will be thickened up to 5% solid consistency. The thickened sludge will be transferred to the sludge holding tank under gravity which will then be pumped to BFP units for dewatering. The polymer will be used before thickener and BFP to promote solid separation. The filter backwash water, supernatant from thickener and wash water/ filtrate from BFP shall be directed under gravity to the Outfall tank. Rodding points or other provisions shall be provided throughout the installation to clear sludge blockage without dismantling any pipe section.

3.4.12.1 *Design Basis*

The pre-treatment process for 400 MLD Perur Desalination Plant includes Lamella Clarifier (LC) and Dissolved Air Flotation (DAF) followed by Gravity Dual Media Filter (GDMF). Most of the solids in raw seawater will be eliminated in the Lamella filter, and some lighter particles will be removed in DAF. The concentration of suspended solids in the seawater to GDMF is expected to be less than 5 mg/L most of the time, which will be removed in filter beds. The sludge generation in LC, DAF and GDMF at a peak feed flow rate (42% recovery) and high/average turbidity are given below in Table 16.

Table 21: Indicative Sludge Flow and Dry Solids at Sludge Treatment System

		Lamella	DAF	DMGF	Total
Sludge Flow	MLD	21	10	40	71
Dry Solids (Ton /day)	Peak	276	51	5	332
	Normal	70	17	2	89

The generation of sludge streams from LC, DAF and DMGF will be about 21, 10 and 40 MLD. The primary solid loads will be in the Lamella clarifier and DAF waste streams. The solid load from the DMGF waste stream is expected within 2 tons/day, which is very low compared to LC and DAF. The concentration of solids in the backwash waste from GDMF is expected to be within 200 mg/L which is not sludge, and so a large sedimentation tank will be required to settle its suspended solids. The treatment of GDMF wastewater is not economical and conducive. Therefore, only LC and DAF sludge have been considered for treatment.

3.4.12.2 *Sludge Balance Tank*

The sludge from the Lamella Settler and DAF will be collected in a sludge balancing tank before pumping to the sludge thickener. The sludge balancing tank shall be of reinforced concrete construction.

The Contractor shall provide at least three submersible mixers (2 duty/1 standby). The mixers shall be of the wall-mounted type with coupling devices, guide rails and support brackets. The mixers shall be provided with adjustment for depth and mixing directions.

An overflow line for discharging of excess sludge to the Outfall tank shall be provided. The system shall be complete with all necessary controls and a set of level elements to provide the required controls and alarms. An indicative design criterion for the sludge balancing tank is listed in Table 17.

Table 22: Indicative Design Criteria for Sludge Balancing Tank

Parameters	Unit	Value
Required tank volume	cu m	2592
Number of RCC tanks		1
Tank sludge depth	m	3.5
Tank area	sq m	741
Tank diameter	m	31
Flow Meter		Electromagnetic
No. of submersible mixers		4 (3 duty/1standby in-store)

3.4.12.3 *Thickener Feed Pumps*

Two thickener feed pumps (2 duty/1 standby) shall be provided. The pumps shall be of the submersible non- clog type and be mounted in a wet well within the tank. The pumps shall be automatically controlled by the water level in the sludge balancing tank.

A static mixer or equivalent device shall be mounted on the pump delivery line inside the pumping vault to ensure adequate mixing of the injected polymer within the bulk of the sludge. A manually operated chain pulley block and running beam shall be supplied for removal of the pumps. The indicative design criteria for the thickener feed pumps are listed in Table 18.

Table 23: Indicative Design Criteria for Thickener Feed Pumps

Thickener Feed Pumps	Unit	Value
Design flow	cu m/hr	650
Maximum flow	cu m/hr	800
Minimum flow	cu m/hr	400
Pump type		Submersible non-clog
Discharge head	m	15

3.4.12.4 *Polymer Dosing System*

Two metering pumps (1 duty/1 standby) and all associated polymer make facilities, pipework and valves etc. shall be provided to dose polymer from a polymer storage tank into the thickener feed line at a rate of up to 5 kg per ton of dry solids.

The metering pumps shall be of the diaphragm type driven by a fixed speed motor with manual stroke adjustment, with a 10 to 1 turndown and an accuracy of ±3% over the operating range. An indicative design criterion for the thickener polymer dosing system is listed in Table 19.

Table 24: Indicative Design Criteria for Thickener Polymer Dosing System

Thickener Polymer	**Unit**	**Value**
Polymer Type		Food grade
Polymer dosing concentration	%	0.5
Operating hrs	hrs	24
Polymer dosing rate	kg/SS-T	5
Polymer consumption per day at peak turbidity	kg/day	1650
Polymer Dosing System		
Type		Metering pump
Number, duty		1
Number, standby		1
Pump capacity	m3/hr	0-15

3.4.12.5 *Sludge Thickeners*

The sludge in the sludge balancing tank will be pumped to sludge thickener. The sludge thickener shall have two functions:

- to clarify the supernatant to turbidity below 10 NTU prior to the return of the supernatant to mixing and distribution chamber.
- to thicken the sludge to a concentration of up to 5% solids prior to dewatering using belt filter presses (BFPs)

The sludge thickener shall have a sloping bottom and shall be fitted with a rotating sludge scraper to transfer thickened sludge to a central removal hopper. The scraping gear shall be supported from the tank base and a fixed bridge carrying the central electric drive for the rotating gear. The equipment, including driving motor, gears, shafting and scrapers shall be designed for continuous operation and sized for the most arduous operating conditions. Suitable overload protection for the drive shall be provided to ensure that the sludge shall not overload the equipment and emergency stop pushbutton shall be provided. The scrapers shall be fitted with rotation monitors and overload protection to alarm in the event of a failure.

The supernatant shall overflow a peripheral v-notch weir into a collecting channel and then flow by gravity to the Outfall tank. The supernatant may be directed to the Intake well. In that case, the polymer should be food grade.

The thickener shall have a full diameter fixed bridge complete with a walkway for personnel access to the centre, access stairs to ground level and handrailing, a motor-driven sludge scraper complete with tie bars and tensioning members, all necessary controls, delivery pipework, a stilling well and overflow steel weir plates. Walkways, access steps etc. shall be galvanised. Handrailing shall be of Type 316 stainless steel material. Underwater fasteners shall be Type 316L stainless steel material.

The electric motor, gearbox, etc., shall be provided with a sunshade. The fixed bridge and the stilling chamber shall be steel coated with polyurethane, including the scraper mechanism. Suitable overload protection for the drive shall be provided to ensure that the sludge shall not overload the equipment and emergency stop pushbutton shall be provided. The scrapers shall be fitted with rotation monitors and over-torque protection to alarm in the event of a failure.

An electromagnetic flow meter shall be provided in the supernatant return pipe to the mixing and distribution chamber. The supernatant pipework shall be arranged to ensure that the pipework in the region of the flow meter always remains full. Flows shall be indicated, totalised and recorded at the local control panel and at the central SCADA system HMI. An online turbidity sensor shall be provided in the return pipeline to assess and record the performance of thickener. An indicative design criterion for the sludge thickener is listed in Table 20.

Table 25: Indicative Design Criteria for Sludge Thickener

Sludge Thickener	**Unit**	**Value**
Type		Continuous Circular Thickener
Design flow	cu m/hr	1500
Design inlet solid	kg/hr	13721
Solid loading rate	kg/day/sq m	86
Thickener surface area required	sq m	3830
Number, duty		2
Diameter of thickener	m	35
Hydraulic loading rate	cu m/sq m/hr	0.7
Depth of thickener	m	4
Thickener removal efficiency	%	90
Flow meter on supernatant return pipe		electromagnetic

3.4.12.6 *Thickened Sludge Holding Tank*

A tank shall be provided to store thickened sludge and to act as a sump for the BFP feed pumps. The tank overflow shall pass to the Outfall tank. The tank shall be fitted with continuous level measurement equipment.

The Contractor shall provide two agitators. The agitators shall be mounted on platforms that extend across the tank. The indicative design criteria for the thickened sludge holding tank are listed in Table 21.

Table 26: Indicative Design Criteria for Thickened Sludge Holding Tank

Thickened Sludge Holding Tank	**Unit**	**Value**
Total sludge flow	cu m/hr	240
HRT	hr	4
Required tank volume	cu m	960
Number, duty		1
Depth of tank	m	4
No. of agitators		2

3.4.12.7 *Sludge Dewatering Process*

a) General

Continuous-feed belt filter presses (BFPs) that use the principles of chemical conditioning, gravity draining and mechanically applied pressure shall be used for the sludge dewatering operations. Sludge shall be first conditioned using polymer prior to dewatering on the belt filter press. Polymer (non-food grade) shall be dosed to the sludge via a static mixer. The conditioned sludge shall be introduced on a gravity drainage section where it is allowed to thicken. Following gravity drainage, the pressure shall be applied on the opposing porous belts where sludge is squeezed and dewatered. Each belt press shall be designed and sufficiently automated to involve minimal operator attention.

b) BFP Feed Pumps

The BFP feed pumps shall be progressive cavity pumps.

c) BFP Requirements

The indicative design criteria for the BFP dewatering system are listed in Table 22.

Table 27: Indicative Design Criteria - BFP Dewatering System

System	**Unit**	**Value**
BFP Feed Pumps		
Type		Progressive cavity pump with VFDs
Minimum capacity	cu m/hr	24
Maximum capacity	cu m/hr	30
Number, duty		15
Number, standby		3
Belt Press Filter		
Design flow	cu m/hr	240

System	Unit	Value
Design flow	cu m/day	5760
Operation times (minimum)	hr/day	16
Required BFP capacity	cu m/hr	360
Number, duty		15
Number, standby		3

d) Polymer Dosing System

All associated polymer makeup facilities, calibrator, pipework, flowmeter and valves etc. shall be provided to dose polymer from a polymer tank into a static mixer on the BFP feed lines. The metering pumps shall be of the diaphragm type driven by a fixed speed motor with manual stroke adjustment, with a 10 to 1 turndown and an accuracy of ±3% over the operating range. The metering pump shall start and stop simultaneously with the associated BFP feed pump. The indicative design criteria for the BFP polymer dosing system are listed in Table 23.

Table 28: Indicative Design Criteria for BFP Polymer Dosing System

BFP Polymer Dosing System	Unit	Value
BFP Polymer		
Polymer Type		Non-food grade
Polymer dosing concentration	%	0.5
Operating hrs	hr	16
Polymer dosing rate	kg/SS-T	5
Polymer consumption per day	kg/day	2223
Polymer Tanks		
Type		Circular tank
Number, duty Tank		2
Polymer Dosing Pumps		
Type		Metering pump
Number, duty		15
Number, standby		3

3.4.13 **Functional Design Specification**

3.4.13.1 *General*

Before commencement of software development for the PLC/SCADA system, the Contractor shall prepare the Functional Design Specifications (FDS) for the plant processes. The Contractor shall be fully responsible for collecting all relevant data and information such as process parameters, alarm setpoints, interlocks etc. required to develop the FDS. Information collection by way of posting a Request for Information is not acceptable. FDS shall be prepared as per the guidelines given in the bid document.

3.4.13.2 *Plant Interlocks*

The FDS shall comprise a listing of all plant interlocks. The plant interlocks shall include but not be limited to

- interlocks between various process units
- interlocks within a processing unit
- interlocks between equipment
- interlocks within a piece of equipment

It is also the responsibility of the Contractor to identify any new equipment type interlock that may not be shown on the Standard Starter Templates. All these interlocks shall be presented in the form of a table and may also be presented in the form of a spider diagram or any other means subject to approval by the Engineer.

3.4.14 **Hydraulic Profile**

The Contractor shall provide the hydraulic profile of the complete seawater desalination plant including the intake pumping station, inlet chamber, flash mixing, flocculation and Lamella clarification, DAF, media filtration, RO system, Remineralization, disinfection, product water storage, sludge treatment and any other water treatment plant process.

3.5 Material Selection and Corrosion Control

The material selected for each equipment item shall have a proven track record for that same equipment item in an equivalent operating environment. The selected material shall be clearly indicated in the Contractor's Proposal Attached to the Contract. The material selection for all major equipment including pipes, pumps, valves, gates, joints, meters, tanks etc. shall be submitted to the Employer for approval during the design phase.

The quality of all materials, prefabricated parts and instruments as well as the quality of workmanship during assembly and erection shall be such that the plant shall have its operational life as defined in bid document elsewhere. The equipment shall be of a well-proven design and renowned manufacturer. The latter shall demonstrate that the proposed equipment has been installed in other plants running successfully under similar conditions. Moreover, in the selection of equipment, the Contractor shall take into account that workshops and offices of the vendors exist in the region.

The Contractor shall indicate the corrosion/erosion allowances intended to be applied based on the operational life for the whole installation.

At locations where the contact between different metals cannot be avoided, protection against corrosion due to galvanic potential difference shall be provided. Where necessary, bolted connections of dissimilar materials shall be insulated from the surrounding metals by means of insulating washers and sleeves to prevent electric current to circulate and establish a galvanic element.

All external stainless-steel components shall be protected against salt deposits

The design and the construction shall be performed so as to avoid crevice corrosion.

External bolts, nuts and washers shall be of corrosion-resistant material.

Any rubber or plastic parts, coatings etc. shall be provided with suitable protection against the ultraviolet radiation of the sun.

Fittings like valves, filters, pumps etc. shall be standardised as much as possible (made by the same manufacturer) to minimise spare parts inventory. The spare parts shall be fully documented, and clearly identified in related drawings.

Workmanship and general finish shall be of first-class commercial quality and in accordance with the best workshop practices and shall provide what is generally recognised as waterworks finish as defined elsewhere.

All similar items of plant and their component parts shall be completely interchangeable. Spare parts shall be manufactured from the same materials as the originals and shall fit all similar items of plant. Machining fits on renewable parts shall be accurate and to specified tolerances so that replacements made to manufacturer's drawings may be readily installed.

All equipment shall operate without excessive vibration and with a minimum of noise as defined in the bid document elsewhere. All revolving parts shall be dynamically balanced so that when running at all operating speeds and any load up to the maximum, there shall be no vibration due to lack of balance.

All parts which can be worn or damaged by dust shall be totally enclosed in dust-proof housings.

Dynamic balancing of rotary components shall be to the relevant standards. All bearings shall have L-10 rating life of minimum 16,000 hours.

3.5.1 **Requirements for Materials**

Materials selected by the Contractor shall be proven to be eligible and sufficient for the RO Plant design life. All materials and equipment shall be designed for long life and shall be suitable for continuous 24 hours per day operation for prolonged periods with a minimum of maintenance. The Contractor may be called upon to demonstrate this for any component either by the service record of similar equipment elsewhere or by records of extensive type tests.

All materials incorporated in the Works shall be the most suitable for the duty concerned and shall be new and of first-class commercial quality, free from imperfections and selected for long life and minimum maintenance.

All parts in direct contact with various chemicals shall be completely resistant to corrosion, or abrasion by these chemicals, and shall also maintain their properties without aging due to the passage of time, exposure to light or any other cause.

Seawater pumping pipes and all pipes and fittings in Pre-Treatment area shall be manufactured in GRP in accordance with AWWA C 950.

Pipe and fitting for low-pressure system and reject (low pressure) shall be GRP of minimum pressure rating of PN10. The piping material for permeate/ product water shall be GRP of pressure rating PN25 as a minimum.

The pipes shall have a minimum stiffness of 2500 N/m^2 in accordance with AWWA C 950 and shall include an internal and external corrosion barrier. These pipes shall also be designed for the full vacuum conditions that may occur in the piping system and shall be designed to withstand the pressure scenarios that occur during the surge condition.

Components of the RO Plant which are in contact with Seawater or are subject to abrasion or potential high rates of wear shall be selected from proven grades of high corrosion/erosion-resistant materials.

All stainless-steel material in contact with seawater and concentrate (brine) in minimum shall have a Pitting Resistance Equivalent Number (PREN) and Crevice Factor (CF) as follows:

PREN = Cr(%) + 3.3 x Mo (%) + 16 x N (%) for austenitic material or

PREN = Cr (%)+3.3 x Mo (%)+30 x N (%) for Duplex material ≥43

CF = Cr (%) + 3 x Mo(%) + 15 x N (%) of not less than 35.

Material for desalination major process pumps (Seawater supply, Seawater booster and high-pressure pumps) shall be super-duplex stainless steel with a PREN ≥ 43. The materials of the other balance of plant equipment and systems shall be suitable for the services intended.

Cathodic protection system as applicable shall be provided to mitigate the corrosion that may occur due to a combination of different materials.

Particular attention shall be paid to the prevention of corrosion due to the close proximity of dissimilar metals. Where it is necessary to use dissimilar metals in contact, these shall be selected so that the bimetallic corrosion is as low as possible and the dissimilar metals shall be isolated by barriers or isolating material. The publication by H. M. Stationery Office (in the U.K.) entitled "Corrosion and its Prevention at bimetallic Contacts" shall be used as a guide.

All outdoor instruments shall be provided with locked, in FRP/GRP enclosures, or of any other equivalent suitable material which shall withstand the corrosive sea environment.

Butterfly valves for On-Off service and non-return valves that are in contact with seawater shall have a Ductile Iron body with hard rubber lining. Control valves for modulating service which is in contact with seawater and subject to abrasion and high rates of wear shall be of highly resistant materials such as Ni-Al Bronze.

The staircase and platform shall have SS316 handrails for safe climbing and access. All platforms and stairways shall have a minimum clear width of 1000 mm. All platforms, stairways, landings etc shall have SS316 railings and guards.

3.5.2 Materials for Pipelines

Each pipeline shall be constructed in a material compatible with the fluid conveyed through that pipeline, i.e. the materials used in the pipes which are or can be in contact with the untreated or treated water, shall not contain any matter which could impart taste or odour or toxicity or otherwise be harmful to health or adversely affect the water conveyed. Nor shall any pipe be adversely affected by the fluid being conveyed through that pipe.

The Contractor shall provide a table for the components of all process units and the ancillaries with their required materials of construction and recommended coating.

Pipework and valve materials for the following duties shall be as follows or to the approval of the Engineer:

Table 29: Materials for Pipes and Valves

Application / Location	**Material**
Coagulation solution	GRP, HDPE or cPVC
Hypo-chloride dosing line	GRP, HDPE or cPVC
Raw Sea Water, brine discharge, Intake Pumping, Piping in Pre-Treatment	GRP AWWA C950/HDPE Pipe and fitting for low pressure system and reject (low pressure) shall be GRP of minimum pressure rating PN10. The piping material for permeate water shall be GRP of minimum pressure rating PN25.
RO Building High Pressure	Super Duplex with PREN ≥43 and Crevice Corrosion Factor ≥35
Instrument air, all materials (pipe, Flange, fittings, valves) for air	SS-316 L
Wastewater drain line – drain network inside a building	HDPE or uPVC
All nuts, bolts, screws and studs for gland joints, couplings joints and flanges. Prior to assembly, all threads of stainless fasteners shall be coated with a nickel-based anti-seize compound. Where anchors, threaded rods, nuts, washers and fasteners etc. to be embedded in concrete shall be manufactured in Type 316 stainless steel. Wherever possible, chemical set fasteners shall be used.	Type 316L stainless steel

All structural components, not exposed to a corrosive environment, (e.g. walkways, fasteners)	hot-dip galvanised iron

3.5.3 Welding

In all cases where welds are liable to be highly stressed, the Contractor shall supply to the Engineer before fabrication commences detailed drawings of all welds and weld preparations proposed. No such welding shall be carried out before the Engineer has signified his approval of the details proposed. No alteration shall be made to any previously approved detail of weld preparation without prior approval of the Employer.

Welding shall comply with B.S 5135.

Approval of welding procedures shall be as per International / B.S. EN 288-3:1992 standards. Welders shall be qualified to ASME / B.S. EN 287-1:1992. All aspects of fabrication and examination procedures, including pre/post-heating treatment, electrodes, non-destructive Tests (NDT) shall be subject to the approval of the Engineer.

Following codes shall apply for the NDTs:

- B.S. 2600: Radiography;
- B.S. 3923/IS 13311: Ultrasonic Test;
- B.S. 6072: Magnetic Particle Test;
- B.S., 6443: Penetrant Test.

3.6 Instrumentation and Control Works

The entire desalination plant shall be designed for automatic operation to minimize the requirement for manual intervention. Flow rates of main streams, seawater to the pre-treatment section, RO trains' feed water, permeate product water, and so on shall be controlled as per the flow rates and shall be continuously monitored by the flow meters.

The plant's information and operation control system proposed shall be based on the network control system. The Distributed Control System (DCS) shall be configured in redundant control mode deployed and distributed in the field areas of the plant by process locations. The DCS shall function independently and autonomously, such that failure of any one element will not affect the operations of the other elements in the entire system. As a result, the system provides maximum availability and reliability for the operation.

The Proposed DCS system at Desalination Plant with the following features:

- Automation, Monitoring, Process Control, Management & Engineering or machine interface
- Reliable User Guidance
- Redundancy Levels in terms of Controller, Power Supplies, Communication &

Operator Work Station except for IO channel Redundancy.

- Uniform operation
- Modern Object-Oriented Software Structure
- Communication with external system and intelligent field equipment
- Integrated diagnosis & documentation system
- Communication support

The DCS will have the following sub-systems/functions.

- Measurement system
- Control system including closed-loop controls, interlock, protection and sequential control system
- Data bus system for control and communication with the process
- Shall be self-diagnostic both module level and channel level diagnostic
- Man-Machine interfacing system
- Maintenance Engineer's station
- Historical data & retrieval facility
- Alarm management system & Sequence of event recording
- Interfacing with other control systems and equipment
- External network interfaces shall be through an industrial firewall
- Dynamic mimic display, alarm monitoring, report trending, logs calculation and printing outs logs, reports and trends.
- All Peripheral hardware failures are hardwired & system status changes through the soft link as per OEM standard for Alarm logging in DCS.
- Time Synchronization with package PLC's.
- The required instrumentation shall be provided for the Units/Facilities to facilitate the smooth plant automation, alarm, monitoring and recording.
- The automation shall be provided to all the processes at the plant such as for but not limited to the following units/facilities of the plant.
    - All chemical dosing systems
    - Lamella and DAF sludge discharge system
    - DMF backwash systems
    - Pre and Post-chlorination - dose rate shall be controlled based on the level of residual chlorine
    - RO with CIP system

  - Remineralization system and pH adjustment
  - Sludge treatment and waste disposal system

- Alarms and Report Generations - Apart from the above, SCADA system shall receive a signal from all instrumentation, units and processes on a real-time basis at the interval selected by the operator, and it shall generate alarms & various Plant Operation Reports.
- Contractor shall provide the functional specification detailing the operation of equipment in manual and automatic mode, description of interlocks and alarms, and description of inputs and outputs signals.
- The system shall provide an orderly shutdown in the event of the operation of a protective device or an equipment failure. There shall be a means of capturing the sequence of the failures and transmitting them to the SCADA for Root Cause Analysis.
- A list of alarms and other important I/O signal (for determining the root cause of failures) shall be provided for review/modification by the Employer and PMC to be agreed upon.
- A written process control narrative describing the local and remote operation, interlocking, sequencing, and trip logic shall be provided.
- A list of both hardwired and interface I/O signals shall be provided in electronic format (MS Access or Excel)
- Electronic copies of the PLC program, HMI configuration files (if applicable), and a sample of local HMI display screens (if applicable) shall be provided.
- In the event of operating air or electric power failure, design controls, components shall go into fail-safe condition.
- All alarms shall be configured for "closed" under normal operating conditions and "open" to alarm. Alarm contacts provided for the Employer's use shall be wired to easily accessible terminal blocks for field connection.
- Separate Routing: Provide separation for each of the following systems:
- 240 VAC power and control wiring.
- Low voltage DC signal wiring, including milliamp, voltage, thermocouple, and Resistance Temperature Detector (RTD) signals.
- Data communications cables such as coaxial, EtherNet Category 6, two or four-wire RS-232/RS-485.
- Prior to shipment from the manufacturer's facility, the Programmable Logic Controller/Operator-Interface Terminal (PLC/OIT) control systems, I/O modules, panels and other peripheral devices shall be staged and energized for operational testing and demonstration. The Contractor's Electrical Testing procedures shall be submitted for Purchaser review and comment.

3.6.1 **Redundancy Levels of DCS system:**

a. Controller Level : Required set of Redundant Controllers have been considered as a minimum at Central Control Room

b. IO Level: Redundancy is not envisaged for IO level.

c. Communication Level:- The communication redundancy for DCS shall be applied as follows,

   i. Controller to IO Modules -Redundant (communication protocol shall be as per OEM standard)

   ii. Controller to Operator/Engineering Stations - Redundant Ethernet

   iii. DCS to third party control system - Redundant OPC/ MODBUS TCP-IP/ RS 485

   iv. Time Synchronization with GPS Master clock - Redundant through NTP

   v. DCS to MOV's - Simplex Profibus/Profinet

   vi. DCS to Intelligent Master Control Centers (I-MCC's) - Redundant Profibus/Profinet

d. Power Supply Level

   The Redundancy shall be applicable on Power Supply modules which are located at main Controller. Bulk power supply shall be redundant. The system power supply is isolated from field device power/ interrogation supplies.

3.6.2 Central Control Room (CCR) System

The Central control room of Desalination plant shall be facilitated with below,

i. Operator Work Stations (OWS's)

The Redundant Operator Workstations shall be interfaced with DCS controllers by using Redundant Data Bus, and the same will be proposed in Central Control Room of Desalination plant.

ii. Historical Storage and Retrieval system (HSR)

The Redundant Historical Storage stations shall be proposed for storage and retrieval facility will collect and store data and parameters including trends, alarms and events from plant unit DCS database periodically and automatically to removable data storage devices once every 24 hours.

iii. Engineering Station & Laptop

The Engineering station-1No and Laptop -1No shall be proposed in Central Control Room for the operator's immediate updation on Logic & Graphics without affecting Real-time Process monitoring & control.

iv. HART Management System (HMS)

The HART Management system-1No shall be provided for centralized configuration, maintenance, diagnostic and record-keeping of electronic smart transmitter data. It is a dedicated standalone PC based HMS system shall be supplied at central control rooms of Desalination plant.

v. Printers

The Printers shall be proposed in Central Control Room for Printing of Reports, Trends etc..and those are to be interfaced with Hot Redundant LAN so that operators can take prints from multiple stations as and when required with credentials of Administrator.

- One Number of A3- Colour LaserJet Printer
- A-3 / A-4 Black & White LaserJet Printer
- All in One LaserJet Printer

vi. Large Video Screen

Two numbers of Large Video Screens shall be proposed inside the Central Control Room for operator monitoring of entire plant screen systems.

3.6.3 Machine Monitoring Systems

i. Vibration Monitoring System (VMS):

The Vibration monitoring system shall have condition monitoring of bearings of all HT motor drives in a desalination plant. The Vibration Sensors shall be provided for measurement in both X(Horizontal) and Y (Vertical) axis in 90 to each other for each bearing for DE and NDE.

ii. Temperature Monitoring System:-

The RTD sensors shall be supplied by respective Motor & Pump manufacturer for HT Drives (wherever applicable), and sensor output is integrated to Temperature Scanner for interfacing with DCS controller.

iii. Handheld Calibrator:

One no. of Handheld calibrator is provided for all HART transmitters for validation of calibration setting & diagnostics on entire field instrument transmitters.

3.6.4 Plant Communication Protocols:

The plant communication protocol is envisaged in the Desalination plant as below:

a) I-MCC's to DCS: REDUNDANT PROFIBUS/PROFINET

b) VFD to DCS: REDUNDANT PROFIBUS/PROFINET

c) For LT Drive>90kW & HT drives: REDUNDANT IEC 61850 SOFT LINK

d) Time Synchronization with GPS Master clock: REDUNDANT

e) Intelligent MOV's to DCS: NON-REDUNDANT PROFIBUS/MODBUS

f) Substation Automation system to DCS: REDUNDANT OPC

g) Compressed Air system to DCS: NON-REDUNDANT MODBUS RS 485

h) Fire Protection to DCS: NON-REDUNDANT MODBUS RS 485

i) Remote Input & Output (RIO) module panels: These Panels shall be applicable for field instruments communication to DCS system on a redundant basis.

Note: - The **Intelligent Master Control Centres (I-MCC's)** shall be interfaced with the DCS system by using Redundant Fibre Optic Cables for effective monitoring & control on entire plant drives that leads to minimising the plant downtime and huge cost savings in terms of cables also to improve diagnostic features as well.

Other following Systems shall be applicable, and those are:

Management Information System, GPS Clock System, Fire Detection & Alarm System, Public Address & Telephone Systems, Closed Circuit Television (CCTV)

3.6.5 Instrumentation Plan

The following table presents the list of major online sensors for each process units of the Proposed Perur DSP. Apart from this, the Contractor shall provide all the instrumentation system necessary for process control in both the process streams at the plant.

Table 30: Major Online Sensors for Proposed Perur DSP

S. No.	Location	Instruments
1.	Seawater pumping station	i. Travelling band screens - Ultrasonic differential level Sensors ii. Intake pump discharge headers – TOC/ DOC analyzer, Turbidity meter, Differential pressure sensor, Ultrasonic Insertion type Flowmeter, Oil Analyser, Residual chlorine
2.	Chemical building - Pre-treatment	i. The dosing tanks will be provided with Online Non-Contact Radar Type level sensor, and the dosing pumps will be provided Electromagnetic flowmeter at pump discharge headers for the following chemicals - NaOCl (Chlorination), Sulphuric acid, Ferric Chloride, Polyelectrolyte etc.
3.	Pre-treatment – Lamella Settler	i. Lamella Settler Common effluent outlet - Turbidity meter, TOC/ DOC analyser. ii. Electromagnetic meter on the sludge

S. No.	Location	Instruments
		discharge line.
4.	Pre-treatment – Dissolved air floatation	i. Dissolved Air Floatation Common effluent outlet - Turbidity meter, TOC/ DOC analyser. ii. Electromagnetic meter on the sludge discharge line.
5.	Pre-treatment – Gravity dual media filtration	i. Gravity Dual Media Filtration Common Filtrate outlet– Turbidity meter, Online chlorine analyzer, TOC/ DOC sensor, Silt density Index analyzer, ORP analyser ii. Differential Pressure sensors at each Gravity dual media filtration unit, Ultrasonic level sensors at each filter. iii. Filtrate magnetic flowmeter at each filter. iv. Backwash pump discharge header- Electromagnetic meter
6.	Pre-treatment – RO feed/ Backwash tank	i. Ultrasonic level sensors
7.	Chemical building for Seawater Reverse Osmosis (SWRO)	i. The dosing tanks will be provided with Online Non-Contact Radar Type level sensor, and the dosing pumps will be provided with Electromagnetic flowmeters at pump discharge headers for the following chemicals - Sodium hydroxide, Antiscalant and Sodium meta-bi-sulphite, Bioxide (as needed)
8.	RO building	i. RO feed pump discharge header – Online Pressure sensor ii. Micron Cartridge filter – Differential Pressure sensor iii. Micron cartridge filter outlet – Conductivity, ORP, pH, Temperature, Alkalinity, SDI Sensor iv. SWRO High-pressure pump suction – Electromagnetic flow meter, Online Pressure sensor v. SWRO High-pressure pump discharge – Online pressure sensor vi. ERD booster pump discharge – Online Pressure sensor vii. CIP dosing tanks- Online non-contact radar type level sensor viii. CIP dosing pumps discharge header – pH,

S. No.	Location	Instruments
		Online Pressure sensor ix. RO flushing pump discharge header – Online Pressure sensor, Electromagnetic flowmeter x. RO permeate line outlet – pH, Conductivity, Boron, Electromagnetic flowmeter xi. RO pressure vessels – Online Differential Pressure Sensor in every individual Pressure vessel
9.	RO permeate tank	i. Ultrasonic level sensor ii. Float type level sensor
10.	SWRO Reject discharge line	i. Electromagnetic flowmeter, Online Pressure sensor, Temperature, pH, Turbidity, Conductivity, Residual Chlorine
11.	Post-treatment area	i. Lime filter inlet/outlet – pH, Electromagnetic flowmeter ii. Lime filter backwash – Electromagnetic flowmeter, residual chlorine iii. Lime filter Backwash air blower- Online Pressure sensor iv. All required sensors and flow meters for CO2 generation and injection. v. The dosing tanks will be provided with Online Non-Contact Radar Type level sensor, and the dosing pumps will be provided Electromagnetic flowmeter at pump discharge headers for the following chemicals – Sodium hydroxide and Sodium hypochlorite
12.	Potable water storage tank	i. Ultrasonic level sensor in the tank ii. Float type level sensor in the tank iii. Potable water storage tank outlet line – Electromagnetic flow meter, Boron, Conductivity, pH, Turbidity, Residual chlorine, Temperature.
13.	Autosamplers	i. Seawater intake area ii. Lamella/DAF effluent and sludge line iii. Gravity dual media filter outlet iv. Reminerlised water lines v. Product water lines to CWR vi. Seawater/ Brine outfall discharge area
14.	Package sewage treatment Plant	i. Inlet Electromagnetic flowmeter and treated water flowmeter and all other

S. No.	Location	Instruments
		process sensor
15.	Wastewater treatment units	i. Lamella clarifier sludge discharge common line – Electromagnetic meter ii. DAF sludge discharge common line – Electromagnetic meter iii. Sludge balance tank and Thickeners - Ultrasonic level sensor iv. Sludge holding tank -Ultrasonic level sensor v. Sludge transfer pumps discharge header to thickener- Electromagnetic flowmeter, Online Pressure sensor vi. The dosing tanks will be provided with Online Ultrasonic level sensor and the dosing pumps will be provided Electromagnetic flowmeter at pump discharge headers for the Polyelectrolyte dosing in Thickener inlet and Belt filter press inlet vii. All pumps pump discharge line – Electromagnetic flowmeter, Online Pressure sensor viii. Neutralisation pit – Electromagnetic flowmeter, Online Pressure sensor. ix. Outfall tank -Ultrasonic level sensor

Notes:-

a) The Instruments which will be supplied along with respective vendor package to fulfil the requirement of entire plant automation.

b) The Vibration Monitoring System & Temperature Monitoring System shall be applicable for each HT Drive.

c) The Drives which are operated through Variable Frequency Drive (VFD) is controlled either with Flow Feedback or Step Logic.

d) The Dry Run Protection is mandatory for each drive.

e) The Overflow Protection is mandatory for each tank.

f) The following systems shall also be applicable along with the DCS system like Hart Management System, Management Information System, GPS Clock System, Fire Detection & Alarm System, Public Address & Telephone Systems, Closed Circuit Television (CCTV)

3.6.6 **Critical Control Points**

The below table shows the Critical control points for the Proposed Perur DSP.

Table 31: Critical Control Points

Control Points	Location	Parameter
CCP -0	Filtrate from DMF	Turbidity < 0.5 NTU, TOC < 2 mg/L, SDI < 3 (95% of time), SDI < 4 (100 % of time)
CCP -1	RO feed pump discharge (Cartridge Filter outlet)	Turbidity < 0.2 NTU, ORP -300 mV, TOC < 2 mg/L, SDI < 3 (95% of time), SDI < 4 (100 % of time)
CCP – 2	SWRO permeate	TDS < 350 mg/L (derived value from Conductivity), Boron < 1.0 mg/L
CCP - 3	Potable water storage tanks discharge line for both the streams	TDS ≤ 450 mg/L, Residual Chlorine < 1.0 mg/L, Boron < 1.0 mg/L, Turbidity < 1.0 mg/L
CCP - 4	Outfall tank discharge line to sea*	TSS < 100 mg/L Iron < 3 mg/L Residual Chlorine < 1 mg/L Temperature – Shall not exceed 5°C above receiving water temperature

Note : * - The values are discharged are based on General discharge standards of CPCB.

Dump lines are provided at the critical control points CCP-1 and CCP - 3, and The following dump lines shall be included which shall be automatically operated based on signals from online analysers. The size of the automatic valves, pipes, etc. shall be for a full dump of off-specification water. Online analysers, automatic valves shall be provided which shall also send signals to DCS.

Dump line No. 1 - In case of chlorine in feed water to RO (due to high ORP), a dump line shall be provided for transferring the full quantity to the Seawater pumping station Intake pit

The online sensors at CCP -1 Turbidity and ORP are duplicated as turbidity and ORP measurement being critical, in the unlikely event of failure of one turbidity meter/ ORP meter, the other meter will take over. Also, in case of anyone, turbidity/ ORP set point was above the desired setpoint, an alarm is annunciated. If both turbidity meters/ ORP meters desired setpoints are above the set value, the online valves would be automatically opened for dumping.

Dump line No. 2 - In case of any parameter of potable water (mainly Boron & TDS) goes beyond the guaranteed value; a dump line shall be provided for transferring the full quantity of the potable water to the Seawater pumping station Intake pit

Similarly, for dump line No.2- the online sensors and electromagnetic flowmeter at CCP -3 namely Boron, Conductivity, pH, Turbidity, Residual chlorine, Temperature are not duplicated as the electromagnetic flowmeter, and the indicated sensors would also be provided in individual Stream A and Stream B.

Duplication of sensors shall essential every location based on the criticality of Process requirement.

3.6.7 Online Monitoring Locations

The Table below indicates online monitoring locations of water quality for the proposed Perur DSP.

Table 32: Major Sampling and Monitoring Locations of Water Quality

S. No.	Parameter	Raw seawater	Filtered water	Potable water	Marine Outfall
1	Silt Density Index	✓	✓	--	--
2	pH	✓	✓	✓	✓
3	Total Dissolved Solids	✓	✓	✓	✓
4	Temperature	✓	✓	✓	✓
5	Electrical conductivity	✓	✓	✓	✓
6	Turbidity	✓	✓	✓	✓
7	Residual chlorine	✓	✓	✓	✓
8	Boron content	✓	✓	✓	--
9	Langelier Saturation index	--	--	✓	--
10	Oxidation-reduction potential	--	✓	--	--
11	Alkalinity	--	--	✓	--

Online monitoring through Online Analysers of all the above parameters and any other important parameter as needed, shall be provided, and the real-time readings are utilised for monitoring and control through SCADA. TDS and Langelier saturation Index are computed values from online analysers.

Auto Samplers are provided at all locations to collect 24 hourly composite samples and analyzed in the plant laboratory.

3.7 General Requirements

The Contractor shall provide all necessary services to complete the plant construction Works and to make a fully working plant as per the Work's Requirements; these services may include:

- All necessary design as well as all necessary inclusions/accessories to provide a complete and operating system irrespective of whether or not all items are specifically mentioned in the specifications or drawings. All materials offered must be suitable for the environment at the plant site in Perur, Chennai and suited to their duties.
- Equipment identification and pipe markings to clearly identify all components for installation, operation and maintenance purposes.
- Platforms, stairs, handrails, and supports to allow safe access to all equipment, tanks and instrumentation requiring inspection, maintenance or calibration.
- The equipment shall be sited in an indoor environment and will not be subject to exposure. Manufacturer's standard painting systems shall be considered suitable if approved by the Employer.
- Erection of all the items, equipment, instruments and other accessories to form a complete functional water treatment plant system capable of performing all the duties required by these specifications and any additions that Contractor needs to provide for a complete functional seawater desalination plant with sludge treatment facilities.
- Contractor shall provide easily accessible water quality sampling points, on each process tank inlet line and/or outlet line, as required by the Employer. Convenient means shall be provided including all interconnecting pipework, sampling pumps and taps, adequate sink and drainage as required to obtain samples manually and locally from all tanks and inlet/outlet lines. Each sampling point shall be provided with an outlet convenient for the collection of samples for laboratory testing and the connection of a portable quality measuring meters.
- Noise levels shall be contained by the appropriate equipment design. Acoustic enclosures should be used only if other appropriate engineering measures are not practical. Noise at the steady-state operation at peak capacity, startup, and shutdown shall not exceed 85 dB (A).
- Freeboard in new units shall generally be not less than 500 mm. Freeboard if necessary, shall be higher such that in the event of excess flow (flow up to +25%) no overflow takes place and marginal freeboard up to 25 mm shall remain. Freefall shall be kept adequate and meet criteria that in the event of excess flow up to +25%, marginal free fall up to 10 mm shall remain.

3.7.1 **Perur Plant design philosophy**

The Perur project is expected to be the spine of the water production for Chennai and will be operated at its maximal available capacity; therefore, it shall offer the lowest cost (CAPEX and OPEX combined) compared to the other desalination facilities.

Design at every stage shall optimize the Capex and Opex distribution, by using "Net Present Value" computation and implementing the best practices of desalination Industry. While aiming at reducing the Opex, a specific focus at energy consumption will be considered.

3.7.2 **Asset life**

The Design Life of the assets should meet at the minimum the following working duration.

- Civil works, buildings and buried pipelines: 50 years
- Concrete tanks, process chambers 50 years
- Heavy mechanical and electrical equipment 25 years
- Other mechanical and electrical equipment 15 years
- Automation and sensors equipment 15 years
- Metallic reservoir and tanks (not for seawater or brine) 25 years
- Polyethylene tank (or other chemical containers) 10 years
- Pressure vessels 30 years
- SWRO membranes >5 years

3.7.3 **Uninterrupted Power Supply (UPS) Systems**

The Contractor shall provide an uninterrupted power supply for plant instrumentation and control system. The Contractor shall demonstrate the operation of the UPS systems by actually simulating a plant-wide or localised power failure condition (as agreed with the Engineer) and proving that:

- all the process instruments have continued to measure the plant data
- the PLC has been processing these and posting the data to HMI
- the HMI has been performing with no interruption and continue to log and trend these data.
- all the instrumentations, including valves are set in the fail-safe mode.

Refer to Part-2, Section VI, Document A-9 for detailed information of the UPS.

3.7.4 **Service Water System**

The Contractor shall construct a plant service water system. The service water storage tanks shall be provided over chemical buildings and sludge treatment buildings for chemical makeup/preparation, inline chemical dilution and chemical laboratory. The service water shall be fed by duty/standby service water pumps located at RO permeate tank. The storage tanks shall provide at least one-hour storage of service water at average usage rates.

The product water shall be used from the product water tank for the following services:

- housekeeping
- emergency showers and eyebaths in the chemical building, sludge dewatering building, laboratory, chlorination buildings and any other locations
- fire-extinguishing system
- cleaning and flushing

- domestic water system – administrative and all other area/buildings at the plant premises.

Potable water storage tanks of RCC shall be provided at all the buildings where there is the frequent use of service/potable water. All service connections shall be provided with isolation facilities to permit work to be carried out at one point of supply without affecting other users. Independent power and control panels shall be provided for the service water systems. Status annunciation shall be carried out using discrete indicator lights located on the pump starter enclosures.

The following alarms shall be provided at the control panel and the central HMI.

- duty pump failure
- system failure (i.e. both pumps failed or a similar occurrence which prevents the system from working)
- storage tank high level

3.7.5 Piping, Pipe Fittings and Valves

The pipes, fittings and valves shall meet the following:

- All process pipework including valves, fittings, and accessories shall be fabricated of and jointed by materials unaffected by and compatible with the conditions of service anticipated.
- All piping shall be designed based on the maximum anticipated flow rates. In general, the pump suction line shall be designed for the maximum velocity at 0.9 m/s and the discharge line at 1.5 m/s. The velocity in other pipes shall be about 1 m/s.
- Pipe, fittings, and valves shall be made of suitable corrosion-resistant material for the purpose of use. Control valves shall be Type 316L stainless steel or other comparable corrosion-resistant material and be tight shutoff and flanged with pneumatic actuators. Actuators shall fail to a safe position.
- All pipe spools shall be factory tested per current requirements. Piping larger than two inches in diameter shall be flanged.
- Instrument lines shall be Type 316L stainless steel unless the fluid requires a more resistant material.

3.7.6 Dismantling Joints

Dismantling joint shall be provided for ease of erection and dismantling of pump/valves/ flowmeters. The body, counter flanges shall be of Ductile Iron / Cast Iron. Bolts and Nuts of the joint shall be of stainless steel. The joint must allow the dismantling of the valve, pumps, meters, etc., without causing stress to the joints of the attached pipes. The pressure class of the dismantling joint shall be the same as that of the pipe and valve. The seal of rubber shall be NBR. The axial flexibility of not less than 25 mm, and the radial flexibility of minimum 2mm shall be provided. It shall be double flanged with a collapsible arrangement. Flanges shall conform to the flanges of connecting pipe/valve. Dismantling joints on pump delivery and pumping mains shall be subjected to a hydrostatic test pressure of 1.5 times the delivery pressure. Detailed drawings of the dismantling joint shall be submitted to the Engineer for approval. The joints shall be painted with corrosion-resistant coating as per specification given for exposed pipes.

3.7.7 Conveyance Channels/Overflows

The arrangement of all conveyance channels and drain piping inter-connecting the units shall ensure that the units will be capable of taking maximum flow. During emergency conditions, excess flow shall be directed to drain until control is regained in order to avoid flooding and protect the various structures. Based on the same, overflow arrangements shall be made at all units and structures where required.

All overflows will be sized for the maximum flow. Overflows will be discharged by gravity to Plant Outfall tank.

3.7.8 Intercom System

An intercom system shall be provided between the following points within the treatment plant:

- control room
- pump and compressor room with the adjacent main distribution panel room
- laboratory
- chemical buildings
- chlorine buildings
- sludge treatment building
- MCC rooms
- Security Guard House
- Administrative building

3.7.9 Laboratory

The Contractor shall provide a well-equipped chemical laboratory with new meters/equipment to analyse all the required water quality parameters, including the following chemical and bacteriological routine analyses:

- temperature
- pH
- conductivity
- alkalinity
- turbidity
- suspended solids
- total dissolved solids
- residual chlorine
- ammonia

- nitrate and nitrite
- phosphate
- e-coli counts
- BOD/COD
- Oil and grease
- All relevant cations and anions

The Contractor shall supply an advanced HACH multi-analysis kit with chemical reagents and equipment for batch tests on coagulation and flocculation. In addition, the Contractor shall provide the laboratory test glassware such as burette, auto-pipette, flask, beakers (of 25 to 500 ml capacity in 12 number each), graduated cylinders of varying sizes and other equipment and reagents for above chemical analyses. The testing methods shall be as simple as possible and the equipment as robust as possible. The methods shall be described in a Test Manual. Standard methods.

3.7.10 Equipment for Mechanical and Electrical Workshops

The Contractor shall construct two workshops and two stock area – one in each plant stream and supply the equipment and tools listed in the table below separately for the workshops at both the plant streams. The equipment and supplied shall be for use solely by the Owner. The Contractor shall provide any equipment and tools required for his use in the operation and maintenance of the plant during the duration of the Contract. At the end of the operation and maintenance period, the Contractor shall turn over all such equipment and tools in serviceable condition to the Owner.

Table 33: Equipment and Tools for Mechanical and Electrical Workshop

S. No.	Description	Unit	Qty
1.	Vertical drilling machine	Nos.	1
2.	Hacksaw machine	Nos.	1
3.	Bench Grinder	Nos.	1
4.	Miscellaneous items and hand tools with safety equipment	Nos.	Lot
5.	Toolboxes	Nos.	10
6.	Workbenches	Nos.	10
7.	Portable Noise level tester	Nos.	2
8.	Portable vibration tester	Nos.	2
9.	Magnetic base dial gauge	Nos.	2
10.	Portable temperature meter	Nos.	2
11.	Cupboard for tools and portable machines	Nos.	5
12.	Filler gauge	Nos.	2
13.	Precision spirit level	Nos.	2
14.	415V, 3 phase, 50hz, 40kVA portable DG set (trolley mounted) including all necessary metering & protection unit, battery, manual control panel, plug & socket, etc., with	Nos.	1

S. No.	Description	Unit	Qty
	cable and accessories. Acoustic enclosure which complies with all environmental regulations shall be included as a part of the supply.		
15.	Toolbox with all necessary tools fixed spanner, ring spanners, screwdrivers, adjustable jaw spanners, etc.	Sets	4
16.	Hand trolley (500kg capacity)	Nos.	2
17.	Tripod with chain pulley blocks of 1 Ton capacity (6.0m legs)	Nos.	2
18.	Welding set, 400 amp, three-phase regulator type, air-cooled, wheel mounted with 15 m welding cable, 2 m. welding cable for earthing, one welding holder, one welding screen with glass and 3 cable lugs, one pair hand gloves and one wire brush	Nos.	1
19.	Portable hand drill (heavy duty) of capacity 13 mm to 23 mm with ½" drill chuck but with drill bits and drill stand	Nos.	2
20.	Tong tester, 1000 Amp	Nos.	2
21.	Hand crimping tool with dies suitable for cable joining up to 95 sq. mm.	Nos.	1
22.	Hydraulic crimping tool, suitable for cable joining from 25 to 400 sq. mm.	Nos.	2
23.	Hydraulic jack, 5 Ton capacity	Nos.	2
24.	De-watering pump sets of 5 kW with 50 meters hose pipe	Nos.	2
25.	Motorized and handle operated insulation resistor tester, 5 kV (multi-range setting), with battery pack	Nos.	2
26.	Handle-operated insulation resistor tester - 1000 Volts	Nos.	2
27.	Megger, 1000 volt	Nos.	2
28.	Megger, 5000 volts (motorized)	Nos.	2
29.	Insulating oil tester and filter	Nos.	1
30.	Hand grinder (Angle 7")	Nos.	1
31.	Clamp-on Digital Meter (0 - 1000 Amperes)	Nos.	2
32.	Multi-meter (Digital)	Nos.	2
33.	Micro-Ohm meter	Nos.	1
34.	Portable vacuum cleaner/blower (industrial type)	Nos.	2
35.	Aluminium folding ladder - 8 meters	Nos.	2
36.	4 terminal Earth Tester (digital)	Nos.	2
37.	Rubber gloves (33 kV rating)	Sets	6

3.7.11 **Package Sewage Treatment Plant**

Bidder shall provide a Package Sewage treatment plant for treatment of domestic sewage from toilets and Canteens at the plant premises building.

The minimum capacity of the plant shall be 13.5 KLD. The reclaimed water from the package sewage treatment plant shall be used for Landscaping and toilet flushing.

The required reclaimed water quality for reuse shall be as indicated below:

Table 34: Quality of the Treated Domestic Sewage

Parameter	Units	Minimum Outlet Parameter
BOD	mg/l	<10
COD	mg/l	<50
Total Nitrogen	mg/l	<10
Total Phosphorus	mg/l	<1
Total suspended solids	mg/l	<10
Total coliform bacteria	MPN / 100 ml	<100 (desirable)
Residual Chlorine	mg/l	< 1

Bidder shall select a suitable treatment technology to treat the domestic sewage to meet the above-reclaimed water quality. All system shall be designed with equipment and materials suitable to withstand the saline environment. Bidder shall provide inlet and outlet Electromagnetic flowmeters for measurement of wastewater entering Package treatment facility and reclaimed water respectively.

Contractor to submit basic engineering documents of the packaged sewage treatment facility to the Employer for review and approval before execution.

3.8 Quality Assurance

All equipment, materials and Works shall comply with the relevant Indian Standards. Where suitable updated Indian Standards are not applicable or appropriate as per the understanding of the Engineer, approved International standards such as BS 5750 or an equivalent shall be used.

3.8.1 **Policy**

As per the Conditions of Contract of Part-3, the Contractor shall apply the formal requirements of Quality Assurance to the design, supply, construction and maintenance of the Works. This shall be achieved through the implementation of a Quality System compliant with the requirements of BS 5750 or an equivalent International Standard. A positive commitment to Quality Assurance shall be expressed in a formal policy statement given in the Contractor's Quality Manual and to be certified by an external certificate.

It shall be the stated aim of the Contractor to achieve and demonstrate the achievement of quality as expressed by `due care and diligence' of the design, supply, construction and maintenance of the Works as defined by the Work's Requirements. The criteria to define `due care and diligence' shall be explained in the Contractor's Quality Plan and shall embody all of the design, supply, construction and maintenance requirements of the Works.

3.8.2 Quality System

The Quality System shall be fully integrated for all of the Works. This system will be defined by the organisational structure, responsibilities, activities, resources, and events that together demonstrate the capability of the Contractor to meet the stated quality requirements. The Contractor shall ensure that all sub-contractors and sub-consultants establish quality systems and shall supply to the Employer such evidence as is necessary to demonstrate the effective implementation of a quality system in each subcontractor or sub-consultant organisation.

The Quality System of the Contractor and of his sub-contractors and sub-consultants will be subject to periodic audits undertaken by the Employer's Representative. The Employer's Representative will give one weeks' notice of such audits that will involve a full assessment of the performance and efficiency of the Quality System and will include review of the feedback and records derived from the Contractor's monitoring and internal reviews. On a day-to-day basis the Contractor shall afford reasonable availability of staff and documentation for the Employers Representative to assess the implementation of the Quality System. The Contractor shall ensure that all relevant personnel and documentation are available for such audits.

3.8.3 Quality Assurance Plan

The implementation of the Quality System shall be through the establishment of a comprehensive Quality Plan issued to and approved by the Employer's Representative. The documented procedures shall include but not be limited to:

- Management Procedures;
- Design;
- Supply/Procurement;
- Construction;
- Putting to work/Commissioning/Reliability Trial/Performance Test;
- Operator Training and Maintenance;
- Interface Control;
- Quality Performance, Monitoring and Review.

There shall be procedures to control transmission of information across all interfaces both internally (that is, within the Contractor's Quality System) and externally. Those of the latter shall include all Statutory Bodies, Authorities and the Employer's Representative. Formal assessment of any non-compliance with the Quality Plan shall be achieved through periodic reviews undertaken by a team appointed by the Contractor. All deficiencies shall be recorded and appropriate corrective measures shall be assessed, within an appropriate timescale, through subsequent formal reviews undertaken by the Contractor.

3.8.4 Quality Feedback

The system shall include for the reporting back, recording and incorporation into the system of deficiencies noted during the control of the project.

3.9 Safety at Site

The Contractor shall prepare a Safety Plan and submit the same to the Employer's Representative for review within 60 days of receiving the Notice to Commence. The Safety Plan shall be followed at all times by the Contractor and shall contain adequate control measures, in accordance with the relevant protection of property and local laws and regulations as well as internationally accepted good practice, for the prevention of accidents, fires and public nuisance. The Safety Plan shall be implemented properly and diligently throughout the execution of the Works and during the operations and maintenance period.

Contractor's Safety Plan shall make safety provision for, among other things:

(a) Offshore works.
(b) The deep excavations and collapsing sides in trench excavations,
(c) Scaffolds and overhead working,
(d) Working in confined spaces,
(e) Working in seawater/water,
(f) Contractor's Equipment, especially cranes,
(g) Handheld power tools,
(h) Electrical equipment,
(i) Hazardous chemicals, gases and fuels,
(j) The use of protective clothing, and noise protection
(k) The provision of first aid facilities

The Safety Plan shall be developed to ensure zero fatal accidents and zero hazardous incidents/occurrences in all construction works. The Safety Plan shall include descriptions of the company's standard policies and procedures regarding its site organization and procedures, methods and frequency of conducting safety audits at the Site(s), record keeping and reporting, providing safety training for its personnel (including subcontractors), issue and mandatory use of safety equipment, and details of the qualifications and experience of the Bidder's proposed safety officers to be deployed at the Site(s). The Contractor shall provide separate descriptions in its Safety Plan covering the construction phase and the subsequent operations and maintenance phase.

The Contractor shall appoint a Full-Time English-speaking Safety Manager for the Works having experience in this field, who shall be responsible for implementing the Safety Plan. He shall be supported by at least two safety officers who are qualified for such safety works, out of which at least one should be well versed/ have complete knowledge of Hindi and Tamil. The Contractor shall ensure that his staff and labour and his Subcontractors are all fully trained in and aware of good and safe working practices. The Contractor shall ensure that all precautions are taken to safeguard the general public and construction/operating staff from any danger.

All temporary and partially completed works shall be protected by way of barricading, lights, notices and the like. Proper lighting shall be placed for offshore works while jacking through the shore. All excavations and the like are to be protected by barricades at all times and adequately illuminated at night. Warning and diversion signs concerning roadwork shall be suitably placed to give motorists ample warning. During the movement of heavy vehicles across roads or onto roads, men, bearing red flags, shall be in attendance to warn other road users and to generally control traffic safely.

The Safety Plan shall also consider requirements for warning and protection for other risks including overhead and underground cables, pipes or obstructions, or voids, openings, pits and trenches. The Contractor shall ensure that all appropriate measures are implemented. The Safety Plan shall include a policy statement signed by the CEO or equivalent authority of the Organization declaring that safety and loss prevention shall be given the highest practicable priority in all aspects of the Contract. The Safety Plan shall be updated as necessary to cover the activities to be undertaken for operations and maintenance.

3.10 Standards

All work performed and equipment supplied shall comply with the appropriate standards, codes and legislative requirements.

Where there is an apparent ambiguity or conflict between any of the applicable Standards and this Specification, the Engineer shall be notified in writing whose decision shall be binding.

3.11 Regulations, Laws and Permitting

There are several regulations, laws and permitting, which is required to be achieved by the Contractor with the help of the Employer. The details of regulatory compliance requirements for the proposed Perur DSP project are furnished in Table 30 below.

Table 35: Regulations, Laws and Permitting

S. No.	Project Stage	Compliances/ Requirements	Remarks	Agency
1.	Project Development Stage	Coastal Regulation Zone (CRZ) Clearance	Statutory	SCZMA/ CRZ Clearance is already obtained
2.	Project Development Stage	Change of Land use		Concerned government authority
3.	Pre-Construction	NOC from Fire dept.		Fire Dept.
4.	Construction	Registration under The Contract Labour (Regulation & Abolition) Act, 1970 as Principal Employer	Statutory	State Labour Department
5.	Pre- Construction	Other Site/ Location Specific Clearances Required: Forest Dept. Clearance	Statutory	Forest Department, GoTN/ Clearances from the authorities as per the Tamil Nadu Timber Transit Rules, 1968 and amendments
6.	Manufacture,	Storage of chlorine	Statutory	TNPCB/

	Storage, and Import of Hazardous Chemical Rules, 1989	(threshold quantity more significant than 10 tons but less than 25 tons) in WTPs will require clearance		Directorate of Industrial Health and Safety.
7.	Pre-construction	Consent for the erection of offshore structure to be obtained	Statutory	Tamil Nadu Maritime Board. Intake and Outfall structure erection for DSP

- Forest Clearance for cutting trees at Perur to be obtained from Forest Department.
- Approval for the erection of offshore structure to be obtained from the Tamil Nadu Maritime Board.

3.11.1 **Discharge Permit**

The regulatory compliance requirements for proposed DSP are identified for the proposed Perur project, and they are related to waste management and disposal, and ambient noise pollution regulation and control is furnished in Table 31. The Contractor is required to adhere to the condition of the discharge limit. It is in the scope of the Contractor to achieve the required permits with the help of the Employer.

Table 36: Discharge Permit

S. No.	Project Stage	Compliances/ Requirements	Remarks	Agency
1.	Pre-Construction/ Operational Phase	Consent to Operate from State Pollution Control Board under Water Act 1974 & Air Act 1981	Statutory	TNPCB
2.	Pre-Construction/ Operational phase	Authorization under MSW (M&H) Rules 2016 (State Pollution Control Board)	Statutory	TNPCB
3.	Pre-Construction/ Operation phase	Noise pollution (Regulation and Control) rules, 2000 and its amendments, 2010	Statutory	TNPCB

3.12 Plant Commissioning

3.12.1 **Commissioning Plan**

The Commissioning Plan shall include:

- The sequence of commissioning activities, including interdependencies, durations and undertakings to verify the Completion of the Contract has been achieved
- Appropriate Risk Assessments for the proposed undertakings
- Inspection and Test Plans (ITPs) shall be submitted 30 days prior to conducting the tests/checks.

- Lists of equipment, plant, and systems to be commissioned, including the asset numbers allocated to them, and a schedule for commissioning them. These lists must be prepared at least five (5) days before the proposed date of commissioning.
- Non-conformance and corrective action procedures
- Emergency and contingency procedures during commissioning activities
- A list of names of the Commissioning Team formed to implement the Plan and their CVs and qualifications

3.12.2 **Commissioning Team**

The Contractor, along with the Engineer and the Employer's representative, shall form a Commissioning Team. The Commissioning Team shall include, but not necessarily be limited to, the following:

- Contractor's Representative(s) including the Commissioning Manager; Commissioning Engineer, Commissioning Specialists and equipment suppliers (if required)
- Nominated representative(s) of Engineer and the Employer's representative (PMC)

During commissioning, the Contractor shall coordinate the activities of the Commissioning Team. The Contractor shall provide the expertise necessary to commission the equipment, plant, systems and take measures, within the scope of this Contract, to complete the commissioning successfully.

3.12.3 **Stages of Commissioning**

The plant commissioning and testings shall be read along with the Part-2, Section VI, Document A-10 Inspection and Testing Requirements and the provisions of the Clause 9 (Test on Completion) in particular conditions of the Contract. The commissioning shall be completed in four stages, followed by the final process proving test. These stages are:

(i) pre-commissioning checks
(ii) dry commissioning
(iii) wet commissioning
(iv) initial performance tests
(v) process proving

Total estimated period for commissioning is 6 consecutive months (180 days). The first three phases (i.e., pre-commissioning checks, dry commissioning and wet commissioning) shall be carried out in two and half months (75 days) and then initial performance testing shall be conducted in 15 days. After a successful initial performance test, the process proving shall be carried out for the consecutive 3 months duration. During this period, the performance of all the process units, particularly the RO system, shall be evaluated. The propensity of the membrane fouling and the effectiveness of the CIP cleaning shall be evaluated mainly during the process proving test.

Tests and inspections, unless otherwise specified or accepted, shall be in accordance with the accepted ITPs, Inspection & Testing requirements (A-10, Part-2) and relevant Indian standards.

All necessary resources to enable effective testing, including but not limited to all necessary labour, materials, equipment, and instruments shall be arranged prior to the tests. Where equipment items or systems are duplicated in the design to provide 'Duty' and 'Standby' facilities, all items of equipment and/or systems of both the 'Duty' and 'Standby' facilities shall be fully tested in accordance with the suppliers' requirements.

All relevant information and experience gained during these tests, including readings such as flow, noise, odour, vibration, power draw, etc. shall be integrated into the Installation Instruction and Operation & Maintenance Manuals, Standard Operating Procedures (SOPs), Unit Process Guidelines (UPGs) and work-as-executed drawings, including P&I diagrams.

The procedures within the Commissioning Plan shall define how non-conformances shall be managed and rectified. Should the equipment not perform the required function to the level of performance required by design during any test, such failure shall be deemed a defect, and the Contractor shall promptly initiate the non-conformance and corrective action procedures required by the Contractor's Quality Assurance System.

A Commissioning Report shall be prepared at each phase of commissioning to demonstrate the assurance that all the activities associated with the commissioning phases have been successfully completed according to the relevant Standards as stated above and to the satisfaction of the Engineer and Employer's representatives. All Commissioning Reports shall be prepared within seven days after completion of each phase and submitted to the Engineer for approval.

All costs of the commissioning and process proving tests including chemicals, power, equipment, spare parts, manpower, all consumables shall be borne by the Contractor. The bidders should include these costs in their price bids for the Works (Design & Build) Contract.

3.12.3.1 *Pre-commissioning Checks*

After completion of all mechanical and electrical installation, all equipment and instrumentation shall be inspected to verify that they are ready to operate. This includes checking that all bolts are properly tightened, safety guards fitted, no signs of damage are visible, lubrication has been completed, electrical point-to-point testing is successfully completed, operation certificates from statutory authorities are obtained, and generally everything has been checked in readiness for operation.

3.12.3.2 *Dry Commissioning (offline)*

After successful installation and pre-commissioning checks, all instruments where possible, including pressure differential transmitters, process analysers, and flow meters shall be field calibrated. Instruments which cannot be field calibrated shall be checked for accuracy in the field.

Once a written certification of proper installation has been issued by the Contractor, dry commissioning (functional testing) shall be initiated for all equipment. To perform the Functional Test, all valves, controls, and other devices shall be operated to ensure they are functional and ready for wet commissioning and performance testing. All control sequences shall be fully tested unless there is potential for damage to the equipment. All safety and protection devices (e.g. flow switches) shall be tested to ensure that they operate correctly.

The purpose of the Dry Commissioning tests shall be to demonstrate, as a minimum, the effectiveness of the following system components and features:

a) Automatic and Manual START/STOP of all equipment using local panel and SCADA

b) Automatic backwashing at various time intervals

c) Automatic shutoff and alarm for various failure modes

d) Monitoring and recovery of operating data

e) Proper operation of the equipment and instrumentation systems

f) Monitoring and control from a remote workstation

g) Automatic switchover from normal power to emergency power, and emergency power to normal power

h) All control functions, both at local system and remote workstation

i) Operation of all monitoring instruments

3.12.3.3 *Wet Commissioning (on-line)*

Commissioning on-line shall commence with the approval of the Employer. Where practical, the process tanks shall be filled with water, and the control sequences shall be re-tested. A continuous operation of the component for a period of two days to the satisfaction of the Engineer will be deemed to demonstrate satisfactory completion of the wet commissioning of that component. The pre-commissioning checks, dry commissioning and wet commissioning period shall proceed for at least 45 consecutive days or as long as is required to establish the process and meet the required plant performance. As a minimum, the following shall be verified during on-line commissioning:

- Local and automatic operation of all equipment and protection systems
- Operator adjustable set-points
- Alarm initiation
- Demonstration of the system under equipment failure scenarios
- Verification of conformance to specified or guaranteed performance as far as is practical at the initial loading

All the necessary adjustments and tuning shall be conducted until the water treatment plant functions as specified under operating conditions. Tests shall be carried out to verify that the water treatment plant shall operate under the full range of operating conditions, meet the performance requirements of the Contract and the design.

3.12.3.4 *Initial Performance Testing*

After the wet operation has been successfully proven and satisfactorily documented, and all necessary approvals are in place, the initial performance of the plant shall be tested. Successful completion of the Initial Performance Test shall be defined as 15 days of operation without a significant failure in the system and demonstration that system meets all performance requirements established herein. The Contractor shall operate the plant and collect and summarize data to demonstrate that the system meets the performance test requirements for production capacity, pressure limitations, membrane permeate quality, and maintenance and power usage.

A major failure in the system is one that fails to produce product water of the required quality or decreases system capacity below 98 per cent of design capacity for more than 24 hours due to equipment failure considering the quality of the product water is maintained. If the inlet system/Lamella/DAF/DMF/RO system/Limestone filter or any other system fails to successfully complete the Initial Performance Test, the Contractor shall have the option of repeating the test for 15 consecutive days. If the system fails to successfully complete the Initial Performance Test during the second test period, the Contractor shall prepare a written plan within seven days for modifying the system to meet all test requirements. All the cost of this test will be borne by the Contractor.

Reports on the performance of the plant shall be provided every week to the Employer to demonstrate that the system meets the performance test requirements. The reports shall contain the following as a minimum:

- Automatic operation of the system
- Raw seawater quantities and qualities
- Water quantity and quality monitoring at Lamella Settler, DAF, DMF, RO, Limestone filters and Product water tank
- Sludge quality and quantity at thickener and BFP
- Other qualities of process importance
- Chemical usage
- Power usage
- Potable water usage
- All maintenance work carried out
- Any "failures" and rectification procedures
- Any other relevant information

3.12.3.5 *Process Proving*

Process proving shall be carried out as soon as is reasonably practical after the successful initial performance testing of the plant. The product water produced during process proving shall be distributed to the household consumers after certifying the product water quality meets the required drinking water guidelines. The Contractor shall give to the Engineer not less than 7 days notice of the date after which the process is proving test will be carried out. The plant shall be tested continuously for 90 days during which all performance and acceptance criteria shall be proven. The plant operation during 90 days of process proving shall be within the defect liability period.

The Process Proving Period is a continuous operation of a desalination plant for 90 days. During this period, the plant should run without any severe deterioration of the product water quality and quantity, and other performance requirements. In the event that the System or any of the facilities do not satisfactorily achieve the required performance standards during this period, the proving period shall be extended until the Contractor has satisfactorily rectified any deficiencies as may be necessary to satisfy the performance requirements and completed the rest of the proving period, at the risk and cost of the Contractor. A failure in the system is one that fails to produce product water of the required quality decreases system overall production capacity below 98 per cent of the design capacity in 24 hours due to any reason including equipment/unit failure. In the case of more than two events of failure or performance deterioration (deviation from the Contractor's performance guarantees), the test shall be deemed as failed, and the test shall be terminated. The Contractor shall fix the problem first and then repeat the process proving test with the consent of the Engineer for 90 days at their own risk and cost. The event of failure is defined as the 2% reduction in production or deterioration of product water quality in terms of TDS, Boron and other vital parameters in a day of 24 hours.

During the Process Proving Test, the Engineer and Employer's representatives will observe the operation of the desalination plant, but the Contractor shall hold the responsibilities for the complete operation and maintenance of the desalination plant with waste disposal. All costs of operation and maintenance, including spare parts, component replacement and waste disposal as required during the process proving period shall be borne by the Contractor. Any excess in the use of chemical and power above the guaranteed values shall be recorded, and it will be a reason for the failure of the test which may be negotiated for appropriate compensation by the Contractor for the increase in the plant operational cost over 30 years of plant operational life. Any production loss during the process proving period due to issues with product water quality and/or working of the equipment at the plant shall also be compensated by the Contractor at the commercial rate.

The Process Proving Test shall verify the complete operation and functionality of the system when automatically controlled and achieving the guaranteed performance. As a minimum, the following shall be verified:

- Automatic operation of the system (including changeover between duty and standby equipment items)
- Recording and trending of all data
- Demonstration of all equipment at full design capacity
- Recorded flow rates
- Differential pressure at RO membrane
- Projected consumption of chemicals and power
- Verification of conformance to the specified or guaranteed performance

- Guaranteed product water quality: If the system fails to comply with requirements for product water quality, the Contractor shall provide a written plan of modifications in plant or operation to achieve compliance with the requirements. Upon implementation of a plan of modifications, Process Proving test shall re-commence in its entirety.

3.12.4 **Plant Operation & Maintenance**

After successful completion of the Process Proving and submission of all the required documents by the Contractor, the first phase of the contract for construction of the plant will be completed and the O&M phase for 20 years will commence, during O&M period the cost of the chemical and power will be given by the Employer within the guaranteed limit provided by the Contractor in its functional guarantees. Any extra consumption of chemical and power above the guaranteed limit that is required to meet the quality and quantity of the product water, shall be borne by the Contractor. The details of the plant Operation and Maintenance are provided in the Part-2, Section VI, Document A-13.

3.13 Documentation

The Contractor shall finalise documentation (such as FDS, SOPs, UPGs, O&M Manuals, control philosophy, P&IDs, etc.) as soon as practicable at the start of the Process Proving Test. Bidders shall include all costs of documentation in their bid offers. No separate payment will be allowed for any of the work described in this section. The documentation shall apply to all processes, facilities and equipment supplied under the Contract. The documentation shall include the following as a minimum:

a) Functional Design Specification describing the functionality of the PLC, including the process control philosophy

b) Unit Process Guidelines (UPGs): One for each unit process, giving the underlying principles of the unit operation and troubleshooting guidelines for bringing the operating parameters within the specified limits

c) Standard Operating Procedures (SOPs): One for each unit process covering the start-up and shutdown procedures for each piece of equipment, including all steps and actions, both at the HMI screen and in the field. Problem-solving guidelines for tracing equipment faults must be included.

d) Installation Instructions and Maintenance Manuals, including data sheets to clearly identify the particular model and optional fittings and features of the equipment provided

e) PLC Program

f) System Control and Data Acquisition Manual

g) A combined maintenance schedule for all equipment showing all activities required daily, weekly, monthly, quarterly, biannually, annually or at other intervals as specified by the manufacturers. All details of lubricants and other consumables must be included. The activities in the schedule are to be completed and documented by the contractor during the operations period to ensure full compliance with the manufacturers' warranty conditions.

h) As-built Drawings

i) The list of assets commissioned, including the asset numbers and description of the assets and commissioning dates

j) Commissioning Report

k) Process Proving Report

l) Training of the Employer's Operations and Service Provider personnel

The Process Proving Report shall be a compilation and summary of the previous reports required for Contract Completion. It shall follow the history of the commissioning, i.e. chronological diary log of findings, incidents and activities completed and checked including:

a) Plant operating peculiarities and observations

b) Any measurement, checks and settings which may be required by operating and maintenance personnel

c) Results of any testing and inspection

d) Copies and a listing of all electronic media files such as photos, DVDs and the like

e) A comparison between the actual performance measured during the Process Proving Test with the Contract requirements

f) All non-complying points and limitations arising from the commissioning

g) All formal commitments from the suppliers or subcontractor(s) to rectify faults uncovered during commissioning

h) Certification by the Contractor's Designers that the equipment meets its design performance and is ready for the ongoing operation

i) All changes to the operating and maintenance requirements found essential after process proving, shall be reflected in the appropriate sections of the O&M Manuals, UPGs and SOPs which shall be updated at the end of the Process Proving Test.

Delivery of the documentation shall be as follows:

- All Commissioning, Performance Testing and Process Proving Reports shall be prepared by the Contractor within 7 days after completion of each task.
- Seven complete sets of the final documents and one complete set in the latest MS Office and AutoCAD format and in Adobe Acrobat Reader format on USB drive shall be provided to the Employer within 15 days after the end date of the Process Proving Period. This final version shall incorporate all information updated as a consequence of operation during the proving and operations periods.

4. GENERAL REQUIREMENTS

4.1 Introduction

This part of the Specification sets out the general requirements/ standards of plant design /materials to be supplied and the workmanship required to be ensured by the Contractor. All component parts of the Works shall, unless otherwise specified in the particular documents, comply with the provisions of this part or be subject to the approval of the Engineer/ Employer's Representative. Particular attentions shall be paid to a neat, orderly and well-arranged installation carried out in a methodical competent manner.

All information pertaining to the Works to be executed including the information about suppliers, procedures, performances, capabilities, factory acceptance test (FAT) reports and other significant data shall be furnished for review and acceptance by the Engineer/ Employer's Representative, who shall have power to reject any parts which in his opinion are unsatisfactory or not in compliance with the specifications and such parts shall be replaced by the Contractor at no extra cost to the Employer.

4.2 Scope of Work

The detailed scope of work for the Contract has been described in Part-2, Section VI, documents A1 and A3 of Works' Requirements along with technical details of the different components, and the Drawings in Part 2 Section VI C.

4.3 Technical Standards and Regulations

Except where otherwise specified, Plant materials and workmanship shall comply with the requirements of the relevant Indian Standards (hereinafter referred to as IS) issued by the Bureau of Indian Standards, other equivalent International Standards such as those issued by the International Organisation for Standardisation (ISO) may be substituted by the Contractor (so long as they are more stringent than the equivalent IS) at the sole discretion of the Engineer or as may have been agreed in the Contract. If relevant IS standards are not available then at the discretion of the Employer, Contractor shall be allowed to use international standards such as ASTM/ANSI/AWWA/DIN/JIS/BS. All standards used shall be the current version and most safe.

All materials and workmanship not fully specified herein or covered by an approved standard shall be of such kind as is used in first class work and suitable to the climate and conditions in the project area.

Where the requirements of any such standard specification or regulation conflict with the requirements of the Works Requirements or any item on the Drawings, the Contractor shall refer to the Engineer for clarification before proceeding with that portion of the Works.

4.4 Plant Commissioning

After execution of all mechanical and electrical installations, the Contractor shall execute the commissioning as per the procedures indicated below and in Part 2 Section VI A3. The total period for commissioning shall be 60 consecutive days. In the first 45 days pre-commissioning checks, dry commissioning and wet commissioning shall be conducted. In the final 15 days, initial performance of the plant operation shall be tested. A commissioning team shall be formed which will include the representatives of the Contractor, the Employer and the Engineer.

4.4.1 **Pre-commissioning Checks, Dry Commissioning and Wet Commissioning**

Initially, pre-commissioning checks shall be conducted in which all equipment and instrumentation shall be inspected to verify their ready to work status. Then dry commissioning (functional testing) shall be initiated for all equipment. During functional testing, the effectiveness of various system components and features shall be tested and demonstrated fit and ready for wet commissioning. This includes the control sequences and safety protection devices.

The wet testing shall be commenced only with the written approval of the Employer. The complete period for pre-commissioning checks, dry commissioning and wet commissioning shall proceed for 45 consecutive days or as long as is required to establish the process and meet the required performance to the satisfaction of the Engineer.

4.4.2 **Initial Performance Testing**

After successful wet commissioning of the plant, the initial performance test shall be conducted for 15 consecutive days. The Contractor shall operate the plant and demonstrate that the complete plant operation meets the performance test requirements for production capacity, maintenance, and chemical and power usage.

The cost of energy, chemicals and other consumables for operation and maintenance of the plant during the commissioning period including initial performance test shall be borne by the Contractor. The costs towards the Contractor's Representative and other operating personnel during the said period of commissioning, along with cost of tools and spare parts, which are required for operation and maintenance of the plant and equipment during the above commissioning period shall also be borne by the Contractor and shall be included in Contract Price.

In the event that the system or any of the facilities do not satisfactorily achieve the required performance standards during this period, the initial performance testing period shall be extended until such time as the Contractor has satisfactorily rectified any deficiencies as may be necessary to satisfy the performance requirements, at the risk and cost of the Contractor.

4.5 Details and Data by the Employer

The Employer has the following data available and used these in formulation of the Tender Documents. They are listed below and shall be used only as guidelines. The Employer does not, however, guarantee either the sufficiency or accuracy of the data provided. The Contractor has to undergo all investigations needed to finalize the process, civil, electrical and mechanical design.

1. Topographical Survey Data
2. Environmental and Social Baseline Data
3. Meteorological Data and Tidal Data
4. Ground Investigation and Ground Condition Data (i.e. Geotechnical Data, Geological Data)
5. Utility Records
6. Land Ownership Data
7. Ground Water, Surface Water and Hydrological Data
8. Orders, Consents, Permits, Licenses and Compliance Requirements
9. As-Built Records of Existing Infrastructure
10. Quality and Environmental, Health or Safety Systems to Apply
11. Details of Any Risks or Hazards
12. Any Other Physical Constraints

Contractor shall carry out fresh survey, investigation and testing/and all other details necessary for proper planning and work execution. The Contractor shall be required to provide full details of the investigations and analysis for approval of the Engineer.

4.6 Precedence of Works' Requirements

The requirements specified in the Particular Requirements, shall be in addition to those specified in the General Requirements. In case of conflict between the parts, the requirements of the Particular Requirements parts shall take precedence.

4.7 Units of Measurement

All designs, drawings, specifications and manuals shall use SI (kg m s) units and all measurements, dimensions and performance data shall be quoted in those units.

4.8 Programme

In accordance with Clause 8.3 of the Conditions of Contract, the Contractor shall within a time specified in the Contract Data, submit a detailed contract programme for the review by the Employer's representative i.e. Project Management Consultant (PMC) and the approval by the Engineer which shall include details of all temporary and permanent works, construction procedures and methodologies.

In addition to the requirements set down in the Conditions of Contract, the programme shall include the following details:

(a) Contractor's organisational family tree for the Contract including details of all site supervisors and their responsibilities

(b) A statement giving the numbers and categories of supervisory and technical staff and skilled and unskilled labour to be employed on the Works

(c) A list and type details of major constructional plant (including vehicles) which the Contractor proposes to employ on the Works, including programmed dates for order and delivery

(d) Details of the Contractor's methods of working for all operations

(e) A statement giving the proposals for location or locations and sizes of offices, workshops and stores at the Site

(f) A complete resource allocation showing the number of units and allotted times for each unit of constructional plant, materials and labour allocated to each part of the Works

The programme shall be co-ordinated to take into account the requirements of climatic, groundwater and other conditions to provide for the completion of the Works in accordance with the Contract. The programme shall be prepared using MS Project software and shall be submitted in both soft and hard copies (editable copy).

4.9 Important Inputs Required from the Contractor

4.9.1 Topographical Survey and Soil Investigation Agency

The Contractor shall reconfirm the topographical surveys, soil investigations, environmental conditions and all other site conditions available with the Tender Documents. The Contractor shall ensure that the work starts within 14 days of the Letter to Proceed with the qualified agencies to whom the Contractor will use for the purpose.

The Contractor shall also conduct additional investigations and land development as are normally necessary to ensure full and satisfactory designs and safety. The surveys shall be carried out with Total Stations and necessary software shall be used for creating the required drawings.

4.9.2 Field Laboratories

The Contractor shall be required to establish a field laboratory as approved by Engineer, suitably equipped to carry out tests as stipulated in the QA/QC Manual, including all specialized equipment which will be required for testing the material and equipment being supplied under the Contract.

Suitable trained laboratory staff shall be posted with full facility of computerized record keeping. The minimum equipment to be provided in the laboratory shall be as listed below. Additional equipment as may be deemed necessary may be added to the same in due course on requirement of the Employer/Contractor.

In addition to the equipment in the laboratory, the Contractor shall also provide field testing equipment as directed by the Engineer on the various sites where work is in progress.

The Contractor shall provide a laboratory at a suitable site as approved by Engineer for the testing of materials. The laboratory shall have the following facilities required for sampling and testing materials and concrete in the field.

All such facilities shall be provided by the Contractor at no extra cost to the Employer. The following equipment with operators shall be made available at Engineer's request (all must be in serviceable condition).

Table 37: List of Equipment to be provided for Laboratory by the Contractor

S. No.	Description	Quantity
1.	Concrete cube testing machine suitable for 15 cm cubes of 100 tonnes capacity with proving calibration ring	1 No.
2.	Cast iron cube moulds 15 cm size	50 Nos. (Min)
3.	Slump cone complete with tamping rod (as required to suit concrete plan)	2 sets
4.	Laboratory balance to weigh up to 5 kg with sensitivity of 10 gm	1 No.
5.	Laboratory balance of 2 kg capacity and sensitivity of 1 gm	1 No.
6.	IS Sieves for coarse and fine aggregates	2 Set
7.	Set of measures from 5 litres to 0.1 litre	2 Set
8.	Electric oven with thermostat up to 120^{o}C	2 No.
9.	Flakiness gauge	2 No.
10.	Schmidt Hammer	2 Nos.
11.	Elongation index gauge	2 No.
12.	Sedimentation pipette	2 No.
13.	Pycnometer	2 No.
14.	Calibrated glass jar (1 litre capacity)	4 Nos.
15.	Glass flasks and metal containers	As required
16.	Chemical reagents like sodium hydroxide, tannic acid, litmus papers, etc.	As required

Arrangement can be made by the Contractor to have the cubes tested in an approved laboratory in lieu of a testing machine at site at his expense, with the prior consent of the Engineer. The outside laboratory shall also be used for routine testing of cement, reinforcement, coarse and fine aggregate and other items.

The Contractor shall be permitted, by arrangements with the Employer to use such equipment and facilities for testing as may be available with the Employer on terms and charges as fixed by the Employer.

4.9.3 Supervisory Staff for Contractor

The Employer places great importance on the quality and authority delegated to the Contractor's key staff deployed in the field to execute and supervise the works. The Contractor is required to ensure deployment of qualified and experienced staff in sufficient numbers on site to ensure quality. The general requirements shall be as below:

4.9.3.1 *Contract Manager*

Contract Manager shall be a person deployed at the Site by the JV Consortium/Contractor as an overall in-charge for the Contract and shall be deployed at the site office. He shall be delegated with Power of Attorney to sign on behalf of the JV Consortium/Contractor on all issues related to Contract and payments. He should be a senior level staff member of the Lead firm of the consortium.

4.9.3.2 *Senior Managers*

There shall be at least one Senior Manager for each of the major components of the Contract: Intake and Outfall system, Pre-treatment system, RO system, Post treatment system, sludge treatment plant, several buildings and ancillary civil works. There shall be separate managers for each of the plant streams. The Senior Mangers shall have minimum following qualifications:

- Education: B.E. (relevant discipline)
- Experience: Minimum 10 years of general field supervision of Contracts and minimum 8 years' experience in supervision in construction/erection of similar works.

4.9.3.3 *Supervisory Staff*

There shall be supervisory staff with the following minimum qualifications deployed at the Site in sufficient numbers to ensure day to day quality supervision of the work:

Education: B.E. in relevant discipline with minimum 8 years' experience in relevant field or Diploma Holder in relevant discipline with 12 years field experience in relevant field. The minimum number of supervisory staff to be deployed at each plant stream is shown in Table 2.

Table 38: Minimum Supervisory Staff

Works	Minimum Supervisory Staff
Civil	4
Electrical	2
Mechanical	2
Instrumentation	2
Safety Engineer	2
QA/QC Engineer	2

The Contract Manager and Senior Managers shall be deployed at the Site after approval of their CVs by the Employer. Initially the CVs of key personnel to be deployed shall be submitted in the Tender. The staff as mentioned above shall be maintained at the Site when the works on the relevant field are being actively carried out. The Contractor shall arrange and maintain sufficient experienced workers and foremen and other support staff as required on sites in sufficient numbers.

4.9.4 **Minimum Construction Equipment to be brought by Contractor on Site**

The Contractor shall assign the minimum equipment on site for ensuring quality and timely progress of works. The minimum equipment, including but not limited to the equipment described in this Subsection, and shown in Table 3 shall be mobilized by the Contractor at the Site for each plant stream of 200 MLD SWRO desalination plant in working condition. The Contractor should submit the equipment mobilization program in the Tender schedules.

Table 39: Minimum Equipment to be mobilized by Contractor at the Site

Sl. No	Description of Equipment	Capacity/Type	Minimum Number to be Mobilized
A	**Excavation, Transportation, Handling and Erection**		
1.	Dozer/JCB/ Excavators	250 HP	2
2.	Crawler crane		2
3.	Crane – 10 T Hydra		4
4.	Tipping Trucks		6
5.	Ripper		2
6.	Tripods and Chain Pulley Blocks		4
7.	Dewatering Pumps		6
B	**Concreting**		
1	Concrete Batching Plant (Semi-Automatic)	20 cu m	2
2	Concrete Batching Plant (Automatic)	20 cu m	2
3	Concrete Mixers	10/7 and 14/10 cu ft	10
4	Needle Vibrators		20
5	Plate Vibrators for Bedding		10

4.10 Completeness of the Offer

The Contractor shall be fully responsible to ensure that the whole of the Works, including each individual component, is designed and constructed in a manner so that the system as a whole operates as a fully integrated system which is capable of achieving the required output in an efficient and economical manner, and to include all plant, equipment and accessories required for the safe and satisfactory operation of the facilities. To achieve this, the Contractor shall ensure that each individual component performs in a manner which is complimentary to that of all other components.

Any accessories which are not specifically mentioned in the specifications, but which are usual or necessary for completion of the Works and successful performance of the System and facilities shall be provided by the successful Tenderer within the tendered cost.

The Contractor shall, to the maximum extent practical and feasible, endeavor to standardize on the manufacture and supply of plant and equipment so as to minimize the operation and maintenance requirements. The Contractor shall ensure that his designs are "maintenance-friendly" and that all items of plant and equipment are designed and installed in a manner which will facilitate routine and periodic maintenance operations.

4.11 Time for Completion

The whole of the Works, including mobilization, reconnaissance, survey, sub-soil investigations, design, manufacturing, transportation, construction, installation, commissioning, testing and process proving (test after Completion) shall be completed within the scheduled Time (Milestone) for Completion as set out in the Tender Documents Part 2, Section VI, A1. The physical completion of the system and facilities shall be achieved before commissioning.

4.12 Milestones

The Employer wishes to ensure consistent prorata progress on all components of the Contract during the entire Contract period. The key milestones set out in Part-2, Section VI, A1, or such other Milestones as may be proposed by the Contractor and agreed by the Employer at the time of tendering, are proposed to be adopted for periodic review of the progress of various components. These milestones will be the stages when the decisions regarding any delay in the implementation will be taken with a view toward the application of the provisions of Clause 8.0 of the Conditions of Contract.

4.13 Contract Management

The Contractor shall be responsible for administration of the Contract from award of Contract through design, manufacture, manufacturer's works testing, and delivery of Plant to the Site, installation, commissioning, testing and performance proving. For this purpose, the Contractor shall nominate a Contractor's Representative in accordance with Sub-clause 4.3 of the General Conditions of Contract who shall be fully responsible for and undertake this administration.

Specific responsibilities of the Contractor's Representative shall be:

(a) The sole representation on behalf of the Contractor in all discussion, correspondence and matters relating to the Works.

(b) The co-ordination and monitoring of Contract progress, which shall include the preparation of the Contract programme, monitoring of progress and submission of monthly progress reports. At the discretion of the Engineer, regular meetings shall be called at which the Contractor's Representative shall give a full account of the Contract progress and programme.

(c) The co-ordination and checking of designs, drawings and submissions. The Contractor's Representative shall be responsible for co-ordinating the design, technical information and data between sub-contractors. All calculations, drawings and information submitted to the Engineer shall be checked by the Contractor's Representative and certified as having been checked before submission.

(d) Contract communication between the Engineer and the Contractor. The Contractor's Representative shall attend all meetings involving the Contractor and the Engineer

(e) The co-ordination and programming of manufacturer's works tests and the submission of test certificates.

(f) The co-ordination and programming of Plant delivery.

(g) The co-ordination and programming of the installation of Plant at the Site, site tests and take over trials. The Contractor's Representative, although not necessarily based at the Site, shall be responsible for the various sub-contractors. At the discretion of the Engineer regular site meetings will be held during which the Contractor's Representative shall give full account of site progress and programme.

(h) The Contractor's Representative shall also be responsible for producing in advance of the work being undertaken, detailed method statements of any work, which involves or affects the performance of existing equipment, processes, or disruption to existing water supplies.

(i) The co-ordination and preparation of As-Built Drawings and operating and maintenance manuals.

(j) Soft copies of all submissions should be in editable form.

(k) The preparation and co-ordination of training.

(l) The submission of applications for payment.

4.14 Meetings

From time to time the Engineer will call meetings in his office or at the Contractor's office, or at the Site, as he deems necessary, to discuss progress and any technical points requiring settlement. The Contractor's Representative or responsible representative shall attend such meetings. The Contractor shall prepare and submit to the Engineer a daily activity report summarising the main activities undertaken each day.

4.15 Photographs

In accordance with the requirements of Clause 4.21 of the Conditions of Contract the Contractor shall supply digital photographs of such portions of the Works, in progress and completed, as may be directed by the Engineer and specified herein. The photographs shall be the property of the Employer and JPEG files shall be delivered to the Engineer with the prints. No prints of these photographs shall be supplied to any other person without the written permission of the Engineer.

The photographs shall be of the following categories:

- progress photographs
- record photographs
- digital video recording

Photographs shall be properly referenced to the approval of the Engineer, and on the back of each print shall be recorded the date and time of the photograph, the direction in which the camera was facing, an identifying description of the subject and the reference. Similarly, the titles of JPEG files shall include the date and time, and an identifying description of the subject.

Photographs taken for record purposes as ordered by the Engineer or as specified herein shall be supplied with MPEG files, JPEG files and three (3) prints, with one print having the signatures of the Contractor and the Engineer (or their authorised representatives) on the reverse side for the purpose of attestation. If required, the Contractor may at his own expense have an additional print similarly attested for his retention. Digital video files shall be supplied to the Engineer in a format approved by the Engineer.

Photographs of the Works by the Contractor for any other purpose whether for use in India or in any other country shall not be carried out without written approval from the Engineer.

4.16 Erection of Plant

Erection of Plant equipment shall be phased in such a manner so as not to obstruct the work being done by other contractors. Before commencing any erection work, the Contractor shall check the dimensions of structures where the various items of Plant are to be installed and shall bring any deviations from the required positions, lines or dimensions to the notice of the Engineer.

Plant shall be erected in a neat and workmanlike manner on the foundations and at the locations shown on the Approved Drawings. Unless otherwise directed by the Engineer, the Contractor shall adhere strictly to the aforesaid drawings.

The Contractor shall be responsible for setting up and erecting the Plant to the line and level required and shall ensure that all Plant is securely held and remains in correct alignment before, during and after grouting-in. This responsibility shall not be passed to any other contractor.

Any damage caused by the Contractor during the course of erection to new or existing plant or building or any part thereto, the Contractor shall at his own cost, make good, repair or replace the damage, promptly and effectively as approved by the Engineer and to the Engineer's satisfaction.

4.17 Site Labour and Supervision

The Contractor shall provide all the skilled and unskilled labour required, and all necessary tools and equipment, to erect, test and commission the Works within the period agreed in the programme. The Contractor shall not remove any supervisory staff or skilled labour from the Site without the Engineer's prior approval.

4.18 Sub-letting

The Contractor shall not sub-let the whole of the Works. Where any design or manufacture is sub-let, the Contractor shall not be relieved of his obligation under the Contract. The Contractor shall be responsible for the acts, defaults and neglect acts in manufacture or design of any sub-contractor, as if they were his own.

Where the Engineer has consented to supply of Plant or execution of work by manufacturers or sub-contractors proposed by the Contractor, such manufacturers or sub-contractors shall not be changed without the prior approval in writing of the Engineer.

A copy of every sub-order shall be sent to the Engineer at the time the order is placed each clearly marked with the title of the Contract and the Contract Number.

4.19 Temporary Works

Not less than 14 days before commencing any portion of the Works, the Contractor shall submit to the Engineer for his approval comprehensive drawings and calculations for all Temporary Works which the Contractor proposes for the construction of that part of the Works.

Notwithstanding approval by the Engineer of any design for the Temporary Works, the Contractor shall be entirely responsible for their safety, efficiency, security and maintenance and for all obligations and risks in regard to such Temporary Works specified or implied in the Contract.

4.20 Languages

All design and drawings (including patented), instructions, signs, notices, name-plates, etc. for use in the design, construction, operation and maintenance of the Works shall be in English. All site sign boards and warning signs shall be in Tamil, Hindi and English.

4.21 Drawings and Information to be provided

4.21.1 General

The drawings that are prepared and issued for this Contract shall be classified as follows and where relevant shall be to a scale which is suitable for the representation of those details illustrated.

The term Drawing shall be deemed to include all drawings, schedules, lists, software documentation, descriptive text and calculations necessary for the design, construction, operation and maintenance of the Works and referred to in this clause. The Contractor shall submit all the drawings (A1 size) and documents on (A4 size) in hard as well as soft (editable) format.

4.21.2 Pre-Contract Drawings

The Pre-contract Drawings are those issued to Tenderers either with the Tender Documents for the purpose of illustrating and clarifying the Works described in the Works' Requirements or later during the tender period as part of an Addendum to the Contract Documents.

Such drawings shall be deemed to have been issued for the guidance of Tenderers and shall, for the purpose of executing the Works, be superseded by the Construction Documents.

4.21.3 Tender Drawings and Documents

The Tender Drawings and Documents are those furnished by a Bidder with his Bid for the purpose of illustrating and clarifying his proposals which will be used in the bid evaluation. These include:

- Layout Plan
- Process Flow Diagram
- Hydraulic Profile
- Building Preliminary GA
- Description of the proposed Intake/Outfall system, Pre-treatment, SWRO Desalination, Post-treatment Processes, Waste Treatment and Disposal system, Building, Tanks and all allied works
- Process and Instrumentation Diagram (P&IDs)
- Single Line Diagram and Electrical Load List
- Chemical Usage

The above information is important and the absence of these in the submitted bids by the bidders, shall be considered non-compliance of the bid and the bid may be rejected.

4.21.4 Construction Documents

The Construction Documents are certified Drawings submitted by the Contractor to the Employer or his Engineer during the course of the Contract for approval. The Contractor shall supply to the Engineer five (5) copies each of the initial design calculations for the process and sizing of all components of the System including architectural, structural, process, mechanical, electrical and instrumentation equipment, supported by design calculation (excel spreadsheets), flow diagrams and general arrangement drawings for approval. It is a matter of high priority that the Contractor ensures the submission and finalization of such designs and drawings in the stipulated time schedules as elaborated.

It is the intention of the Employer to ensure that the approval of such submissions is made expeditiously and in time. The Contractor is therefore required to setup his project office in Perur, Chennai (fully equipped and staffed) to enable continuous submission, interaction and timely clearances.

The Employer shall arrange to send observations if necessary, within twenty-eight (28) days of submission of the design and drawings for modifications to the Contractor. The Contractor shall incorporate all necessary comments of the Engineer in the above design and drawings, if any, and shall re-submit further five (5) copies each of the revised design and drawings within ten (10) days for final approval of the Engineer.

The Contractor shall thereafter submit seven (7) copies each of the approved design and seven (7) copies each of the approved drawings together with one copy each of the reproducible tracings. The Engineer will return two (2) approved copies to the Contractor and retain five (5) for the Engineer's office and field use.

If the submissions require more than one round of revision on account of incomplete compliance from Contractor, the delay shall be on account of the Contractor. If new observations are given by the Engineer based on the initial submission, the Contractor shall be entitled to take an additional ten (10) days period for compliance. Further design calculations and drawings shall be submitted in sequence as per a schedule to be drawn and agreed upon mutually, immediately after submission of the general arrangement drawings.

A blank space 90 x 50 mm shall be provided immediately above the title block for the approval stamp. If required in the document elsewhere, the detailed design and the execution drawings shall be submitted only after verification by an Institute approved by the Employer. The Contractor shall be responsible for preparation of working drawings and the construction documents for Works, as specified in the Contract.

The Engineer may require the Contractor to submit for approval additional drawings if they are necessary to enable him to satisfy himself that the items are well designed, that they comply with the Works Requirements and that they are suitable for their intended purpose. These drawings shall form the agreed basis for the execution of the Works. If an approved drawing is revised, revised copies shall be submitted for approval as above and no such revised drawing shall be used for the purposes of the Contract until it has been approved in place of the earlier issue of the drawing.

Approval of drawings by the Engineer shall not be held to relieve the Contractor of his responsibilities under the Contract. The Engineer will not permit construction to start on a part or section of the Works unless Construction Documents for that part or section have been approved.

4.21.5 Drawings for Approval

Drawings for approval shall be submitted in two (2) phases both in hard as well as in soft (editable) formats. The first phase shall be the Preliminary Drawings. Drawings submitted during this phase shall be of sufficient details for the Engineer and Employer's Representative

(PMC) to understand in outline the Contractor's proposals for the design and construction of the Works.

The Preliminary Drawings shall inter alia comprise:

- comprehensive description of the process, the plant offered, its operation
- control philosophy
- treatment works hydraulic profile including hydraulic calculations
- chemical process and mass balance & flow calculations
- treatment works flow diagram including details of flows in each area of the plant
- preliminary process and instrumentation diagrams (P&ID); the diagrams shall indicate in symbolic form (to BS 1646 and BS 1553) the process, plant and systems of measurement, control and automation
- site layouts including information on levels detailing the location of:
    - buildings
    - process plant
    - storage tanks
    - transformer enclosures
    - roadways
    - buried pipelines
    - main cable routes

- civil works plans, elevations and main sections of all buildings
- site drainage details
- contract interface details
- general arrangements and main sections of all plant areas
- electrical single line diagram based on approved mechanical and process load list showing CT & PT details, starter details, cable sizes, feeder metering and protection details, equipment capacity and sizes, feeder Interlock operation logic, DG set starting and stopping operation logic, panel cable entry details, panel busbar capacity and sizes etc.
- a description of building services provisions proposed for the Works
    - control system architecture
    - load schedule
    - instrument schedule
    - I/O schedule for each PLC

The Preliminary Drawings shall be submitted by the Contractor for approval as a single submission.

The second phase shall be the detailed design phase and shall comprise the submission of the Construction Documents. These shall be submitted after approval of the Preliminary Drawings by the Engineer. The Construction Documents shall be used for the construction of the Works and shall inter alia comprise:

4.21.5.1 *Civil*

The Contractor shall comply with the provisions of the requirement of the Specifications for Civil Works, as applicable.

Materials, Plant and Equipment

The Contractor shall place orders for the material and the equipment only after approval of the Engineer. The Contractor shall submit the detailed drawings from the approved manufacturers and the procedure of submission, review and revision shall be as specified herein below.

The Contractor shall inform the Engineer about the likely dates of manufacturing, testing, and dispatching of any material and equipment to be incorporated into the Permanent Works. The Contractor shall notify the Engineer for inspection and testing, at least twenty-eight (28) days prior to packing and shipping and shall supply the manufacturer's test results and quality control certificates. The Engineer will decide whether he or his representative will inspect and test the material/equipment or whether he will approve it on the basis of the manufacture's certificate.

The following inspection and test categories shall be applied prior to delivery of the equipment, of various categories as indicated in the technical specifications for each type of the equipment:

Category A: -The drawing has to be approved by the Engineer and Employer's representative (PMC) before manufacture and testing. The material has to be inspected by the Engineer and PMC at the manufacturer's premise before packing and dispatching. The Contractor shall provide the necessary equipment and facilities for tests and all the related costs for the inspection thereof shall be borne by the Contractor.

The Equipment covered under this category includes all pumps, motors, chemical injection system, chlorination systems, RO system, safety equipment, electric hoists and cranes, screens, strainers, manual hoists of capacity 1 ton and above, valves, gates, nozzles, mixers, agitators, pipes and fittings, meters, actuators, belt conveyor, thickener drives and sludge scraping mechanisms, belt filter presses, 3.3kV/3.3kV switchgear, 33kV/3.3kV/415V transformer, LT panels, distribution boards, MCC, capacitor bank with APFCR, diesel generator set, VFD, battery, battery charger with DCDB and cables.

Category B: - The drawings of the equipment shall be submitted and approved by the Engineer prior to manufacture. The material shall be tested by the manufacturer and the manufacturer's test certificates shall be submitted for approved by the Engineer before dispatching of the equipment. Notwithstanding the above, the Engineer, after examination of the test certificates, reserves the right to inspect the testing or instruct the Contractor for retesting, if required, in the presence of the Contractor's representative

The Equipment covered under this category includes sampling pumps, drain pumps, manual hoists less than 1-ton capacity, ventilation system, exhaust fans, instrument air compressor, filter media, dismantling joints, air-conditioner and lighting fixtures.

Category C: - Samples of the materials and/or equipment shall be submitted to the Engineer for pre-construction review and approval in accordance with the provisions of Sub-Clause 7.2 of conditions of contract. Following approval by the Engineer, the material shall be manufactured as per the approved standards and delivered to the Site.

For material/equipment under Category "A" and "B", the Engineer will provide an authorization for packing and shipping after inspection.

The testing and approval for dispatching of the equipment/plant shall not absolve the Contractor from his obligations for satisfactory performance of the plant.

The civil construction drawings shall comprise the following:

- site layouts providing information on levels and detailing the location of
  - buildings, architectural drawings/renderings
  - storage tanks
  - process plant
  - transformer enclosures
  - roadways
  - drainage
  - buried pipelines
  - cable routes for direct in ground and ducted systems
- plans, elevations and main sections of all structures, foundations and buildings
- general arrangements and main sections of all plant areas
- drainage provisions
- general arrangement drawings showing the location of each Plant item
- detail drawings of:
  - cable and pipework chambers
  - buried pipework
  - pipework connections
  - contract interface
- reinforcement drawings
- bar bending schedules

- The structural design calculation with computer input & output files for the design package program such as STAAD etc.

4.21.5.2 *Hydraulic*

- hydraulic profile
- hydraulic calculations

4.21.5.3 *Process*

<u>Drawings:</u>

- process flow diagram
- comprehensive P&ID s including details of:
- pipeline sizes and materials;
- valve size and type;
- instrumentation;
- identification of controlling PLC.

<u>Calculations for:</u>

- process mass flow;
- process calculations for all processes
- RO projections
- plant load calculations
- chemical processes
- process drains

4.21.5.4 *Electrical*

Drawings

- 33kV/3.3kV Switchgear
  - (a) Dimensional Layout Drawing.
  - (b) Complete assembly drawings of the Switchgear showing plan, elevation and typical sectional views and location of cable boxes and control cable terminal blocks for external wiring connections, etc.
  - (c) Foundation plan showing the location of channel sills, foundation, anchor bolts and anchors, floor plans and openings.
  - (d) Schematic power and control wiring diagrams with control, interlocks, relays, instruments, space heaters, bus bar rating with material, Current transformers, potential transformers etc.

- 33kV/3.3kV/415V Main Transformer
  - (a) General arrangement drawing shall indicate the overall dimensions, net weights, quantity of oil, crane requirements for assembly and dismantling of transformers and the general constructional features.
  - (b) General arrangement drawing of the transformer, showing plan, front elevation and side elevation complete with all accessories and fittings, detailed dimensions, net weights, quantity of, crane lift for un-tanking, size of lifting lugs and eyes, clearances between HV terminals, between LV terminals, between HV and LV terminals, between HV & LV terminals and ground etc.
  - (c) Rating, diagram and terminal marking plates, complete with polarity and vector group
  - (d) Control wiring diagram for marshalling box
  - (e) Foundation drawing with position of foundation bolts and depth

- RTCC Panel for Main Transformer
  - (a) General arrangement drawing shall indicate the overall dimensions, net weights, and the general constructional features.
  - (b) Wiring diagram with tap position details and logic for on line operation

- L.T Panels, Distribution Boards, Power Control Centres, Power Motor Control Centres, Motor Control Centres etc
  - (a) Dimensional layout drawing
  - (b) Complete assembly drawings of the switchboard/distribution board / MCC showing plan, elevation and typical sectional views and location of cable boxes and control cable terminal blocks for external wiring connections, etc.
  - (c) Foundation plan showing the location of channel sills, foundation, anchor bolts and anchors, floor plans and openings.
  - (d) Schematic power and control wiring diagrams with control, interlocks, relays, instruments, space heaters, starter details Bi-metallic relay ratings and contactor ratings, bus bar rating with material, current Transformer, potential transformer etc.

- L.T Capacitor bank with Automatic Power Factor Correction Relay
  - (a) Dimensioned general arrangement drawings of capacitor and capacitor control panel
  - (b) Justification for number of steps for switching.
  - (c) Fully dimensioned general arrangement drawings of capacitor and capacitor control panel with elevation, side view, sectional view and foundation details
  - (d) Complete schematic and wiring diagrams for capacitor control panel

- Battery and Battery Charger with D.C. Distribution board
  - (a) Dimensioned general arrangement drawings
  - (b) Fully dimensioned general arrangement drawings of battery and battery charger with elevation, side view, sectional view and foundation details
  - (c) Complete schematic and wiring diagrams
- Cabling System
  - (a) Details of Installation of Cables in Trenches, on cable trays, directly buried etc at all locations inside the treatment plant.
  - (b) Cable routing lay out inside and outside the plant.
  - (c) Bill of quantities of cables, lugs and glands.
  - (d) 33kV/3.3 kV Cable termination and mounting Kit Layout drawing.
- Lighting system
  - (a) Detailed Room wise Lighting Layout with Type of fixture details and Circuit diagram showing phase wise load distribution and interconnection between switches, fixtures, Lighting panel, receptacles etc.
  - (b) Conduit layout showing room wise routing of wires from lighting panel to lighting fixtures, receptacles etc.
  - (c) Internal road Lighting and Area lighting layout with type of mouting details and fixture details.
  - (d) Street Light pole details with Foundation details
- Earthing System
  - (a) Details such as material, sizes, etc. of the earth conductor and electrode pits
  - (b) Earthing layout drawing showing routing of main grid inside and outside the plant with interconnection of equipment earthing to the grid and earth pits
- Substation Building Layout showing Panel locations, Transformer locations and Trench Layout
- Electrical Equipment and Panel Layout inside and outside the plant

<u>Schedules</u>

- cable schedules
- load and power consumption schedule
- junction box schedule
- protection relay setting schedule
- panel/MCC schedule

<u>Calculations for:</u>

- Cable sizing
- Fault level and Voltage Dip Calculations
- Co-ordinated protection study
- Standby generator sizing based on equipment finalized by Mechanical and Process
- Transformer Sizing Based on equipment finalized by Mechanical and Process
- Room wise Lighting Calculation as per Lux level given in the specification
- Earthing Sizing Calculation
- Panel Busbar Sizing Calculation
- light/lux calculation

4.21.5.5 *Control, Instrumentation and Monitoring System*

Drawings:

- power supply distribution single line and schematics diagrams (see note 1) for each control panel
- internal and external (see note 2) general arrangement for each control panel (dimensional)
- control and instrumentation loop drawings (see note 3)
- instrument installation detail drawing (hook up, see note 4)
- cable block diagrams
- cable routing/installation drawings
- foundation and fixing details and trenches drawings
- schematic diagram for system configuration of PLCs, operator stations, engineering stations, large screen, multi-plexer, training station, report station, printers etc.
- screens of process flows, diesel generator set and HV power incoming panels etc.
- format of reports, alarms etc.

Schedules:

- cable schedule
- cable interconnection schedule
- control and instrumentation load schedule for each control panel
- I/O schedule for each PLC
- control and monitoring item schedule for each PLC and operator station
- alarm schedule
- junction box schedule
- instrument schedule
- instrumentation, process control set point schedule
- instrument data sheets

Documentation:

- functional design specification (FDS) (see note 5)
- factory acceptance test document (FAT)
- site acceptance document (SAT)

Notes:

1. Schematic drawings shall include a comprehensive schedule of the components used in each switchboard, MCC and control panel including details of the type, manufacturer and rating of each component
2. The external arrangement of each switchboard, MCC and control panel shall show the arrangement of all components including details of panel section, switch and instrument labels
3. Control and instrumentation loop drawings shall show on a single drawing of the complete circuit associated with an instrument or device including details and location of power supplies, cabling and terminations
4. Hook up drawings shall detail how an instrument or device is installed
5. See details later for requirements of the FDS
6. Electrical control schematics, loop diagrams and schedules shall where practical be A3 size drawings; all other drawings shall be A1 size

4.21.5.6 *Mechanical*

Drawings:

- general arrangement of plant and pipework including sections
- isometric views of pipework systems
- detail drawings of proprietary and fabricated plant items

Schedules:

- pump curves
- plant performance details
- pipeline schedules
- Valve schedules

Calculations for:

- pump sizing
- pipeline sizing
- compressor sizing
- torque calculations
- Ventilation system
- Actuator sizing

4.21.5.7 *Mechanical Building Services*

<u>Drawings:</u>

- single line schematics for water and sludge handling system and drainage systems
- general drawings showing the location of each mechanical building service plant item
- general arrangement of ventilation systems
- fixing details

<u>Schedule:</u>

- plant data sheets
- pipeline schedules
- valve schedules

<u>Calculations for:</u>

- system sizing
- plant/equipment

4.21.6 **Drawing Format and Numbering**

All drawings shall be prepared using an identical title block format. This shall be approved by the Engineer and shall identify the project, drawing title, the Employer, the Contractor, Sub-contractor, if applicable, and the Engineer.

A formalised drawing numbering system shall be adopted with digits of each number, referencing location, revision, drawing type and size. The numbering format and allocation of drawing number blocks shall be approved by the Engineer. The Contractor shall provide a sequential numbering system for all Construction Documents

All drawings shall be submitted to a formalised checking procedure prior to submission to the Contractor. Drawings not so checked will not be approved.

4.21.7 **Information required on As-Built Drawings**

The As-Built Drawings shall consist of the fully up-dated versions of the approved Construction Documents incorporating any additional information which will assist the Employer in operating, maintaining and if necessary, modifying or extending the Works at a later date. These drawings should extend and supplement the information given in the Operating and Maintenance Manuals.

4.21.8 **As-Built Drawings**

These drawings shall be compiled by the Contractor and shall constitute a permanent record of the Works as executed. These shall include all such drawings, schedules, documentation and calculations as necessary for a complete understanding of the Works design, operation and maintenance.

Draft As-Built Drawings shall be submitted sixty (60) days prior to the commencement of Tests on completion. The Engineer will signify his approval or disapproval of the As-Built Drawings within twenty-eight (28) days of submission.

The Contractor shall supply to the Engineer five (5) copies of the As-Built drawings. The Contractor shall incorporate all necessary comments of the Engineer in the above drawings, if any, and shall re-submit further five (5) copies each of the revised drawing within ten (10) days for final approval of the Engineer. The Contractor shall thereafter submit seven (7) copies each of the approved As-built drawing with one copy each of the reproducible tracings. The Engineer will return two (2) approved copies to the contractor and retain five (5) for the Engineer's office.

A3 and smaller sized As-Built Drawings shall be provided on durable paper for reproduction by photocopier. As-Built Drawings larger than A3 shall be provided as a paper copy and also produced in the form of black lines on a durable translucent film from which further paper prints can be taken by others as required. In addition, drawings shall be provided as an AutoCAD Revision (latest version) soft copy (Editable). Text shall be provided in an industry standard word processing, spreadsheet or database format as appropriate (Editable copy).

4.21.9 **Control System Development**

Within the time scale detailed in the Contract Programme, the Contractor shall submit a control system Functional Design Specification (FDS) for approval by the Engineer. FDS shall be the basis for automation of the total system, process control, and alarms. The FDS shall include as a minimum the requirements described as follows:

- a comprehensive description of the functions to be performed by the control system
- an overview of the control system hardware configuration and indication of the functional responsibilities of all the major hardware components
- the control system functionality description
- hardware configuration (system architecture) block diagrams and software block flow diagrams to provide an understanding of the overall capability of the control system
- a functional description of each part of the control system
- description of the communications functionality
- description of the communication functionality checks
- schedule of all hardware components, including the manufacture's name, model number, weight, dimensions, etc.
- electrical power supply requirements of all hardware
- electrical power supply schematic
- general arrangement control panels, furniture etc.

- equipment rack layout drawings
- room layout drawings

The following schedules for the PLC's:

- I/O schedule
- database schedule

The following schedules for the HMI's:

- screens types and reference numbers
- screens navigational structure
- alarms
- alarms directory structure
- events
- set points
- PID parameters
- trended variables including grouping details (real time and historic)
- archived variables

The FDS shall be divided into separate sections. A typical structure would be as follows:

Section 1	General Description;
Section 2	Detailed System Architecture;
Section 3	Control Philosophy
Section 4	System Functionality PLCs;
Section 5	System Functionality HMI's;
Section 6	Communications;
Section 7	PLC and HMI Schedules.

The FDS shall comprise an overall description of the plant, its functions, control and a detailed description of each section of the control system covering modes of operation, manual over rides, set point and parameter selection & adjustments. FDS shall describe the "fail-safe" features incorporated into the design for the event of failure of a plant item or a system or loss of an input signal affecting a control loop or a process sequence. FDS shall describe the control actions taken and monitoring functions which remain available during a sequencing, which take place during system start-up & shut-down.

4.22 Pre-dispatch Inspections Inside and Outside the Employer's Country

In the event the Contractor proposes to procure material which requires pre-dispatch inspection of the Engineer and Employer's representative (up to maximum 4 engineers) from inside and outside of the Employer's country, the Contractor shall arrange and provide for the cost of the travel to the Manufacturer's place, accommodation, local transport and food for the Engineer and the representatives of the Employer (PMC). Such costs shall be incorporated in the tendered cost under provisional sum.

4.23 Hot Line

During the Contract Period the Contractor shall maintain a 'Hotline' for trouble shooting purposes through which the operators can be contacted in case of problems.

4.24 Tests on Completion of Work

The Contractor shall carry out the tests on completion before Taking Over as stipulated in Part 2, Section VI, A3 and A11.

4.25 Operating and Maintenance Manuals

4.25.1 General

The Contractor shall compile, operating, maintenance and overhauling instructions for the whole of the Plant, and shall consist of separate volumes. The manual shall not be only the collection of the manufacturers' manual but it should include a tailored document for operation, maintenance and troubleshooting of the plant systematically and user friendly. The Contractor shall submit a minimum of seven copies of the Operation and Maintenance (O&M) manuals. The manuals shall consist of:

(a) general descriptive text (including drawings for illustration) of the Works described section by section.

(b) comprising the complete operational instructions for the treatment plant. This shall be termed the Operators Manual. It shall be aimed at the operational staff and shall be written in clear unambiguous text complete with drawings were necessary for clarification of any issues. The manual shall comprehensively detail what to do on a day to day basis and also what to do in the event faults developing. It shall in addition provide a complete list of the process maintenance tasks the operator should carry out including the intervals between these tasks.

(c) the essential instructions for mechanical and electrical maintenance of the Plant. These instructions shall be short and concise and set out in a consolidated schedule the inspection, lubrication, cleaning and any other type of servicing operations required. The Contractor shall prepare typical maintenance log sheets that the Employer can subsequently use for daily, weekly, monthly or other periodic maintenance and shall form record sheets of plant maintenance operations.

(d) instructions for use of skilled maintenance personnel in fault location, carrying out routine replacements, withdrawing, dismantling, overhauling, re-assembling and testing the various items of Plant.

(e) manufacturer's Technical Documentation subdivided into categories for:

- civil
- process
- electrical
- electrical building services
- mechanical building services
- instrumentation and control

(f) Civil As-Built Drawings.

(g) comprising the FDS and PLC code.

(h) electrical As-Built Drawings. The electrical drawings shall be complete sets including all information necessary for maintenance and spares replacement.

(i) control and instrumentation As-Built Drawings. The electrical drawings shall be complete sets including all information necessary for maintenance and spares replacement.

(j) mechanical As-Built Drawings. The mechanical drawings shall be complete sets including all information necessary for maintenance and spares replacement.

(k) electrical and mechanical building services As-Built Drawings. The drawings shall be complete sets including all information including performance curves necessary for maintenance and spares replacement.

(l) FAT records for the Works.

(m) SAT records for the Works

Each volume shall be subdivided (relating to areas of plant) into sub sections or sub-volumes in order to ease the location of plant details. Each volume or sub-volume shall be provided with a comprehensive index for the volume or sub-volume concerned and the O & M manual as a whole.

Draft copies of the O&M manuals shall be submitted to the Engineer for his approval at least sixty (60) days prior to the commencement of Tests on Completion.

The Contractor shall supply to the Engineer 5 (five) copies of the O & M manuals. The Contractor shall incorporate all necessary comments of the Engineer in the above manuals, if any, and shall resubmit further 5 (five) copies each of the revised manuals within 10 (ten) days for final approval of the Engineer. The Contractor shall thereafter submit 7 (seven) copies each of the approved manual together with one copy each of the reproducible tracings. The Engineer will return 2 (two) approved copies to the Contractor and retain 5 (five) for the Engineer's office.

Each volume shall be enclosed within A4 and A3 ring binders have tough grease resistant covers suitable for use on site and designed to permit the easy removal and insertion of the contents. The front cover and spine of each volume shall show details of the project, Employer, Engineer and a volume title.

Text shall generally be enclosed in A4 ring binders, A3 drawings shall be enclosed within A3 ring binders except where it accompanies A4 text in which case it shall be folded. A1 drawings shall generally be folded and enclose in A4 box files. Where A1 drawings accompany text they shall be folded and enclosed in an A4 plastic wallet, one wallet per drawing.

4.26 Notice of Operations

The Contractor shall give full and complete written notice of all-important operations to the Engineer sufficiently in advance to enable the Engineer to make such arrangements as the Engineer may consider necessary for inspection and for any other purpose. The Contractor shall not start any important operation without the written approval of the Engineer.

4.27 Reinstatement and Compensation for Damage to Persons or Property

The Contractor shall reinstate all properties whether public or private which are damaged in consequence of the construction and maintenance of the Works to a condition as specified and at least equal to that obtaining before his first entry on them.

If in the opinion of the Engineer the Contractor shall have failed to take reasonable and prompt action to discharge his obligations in the matter of reinstatement, the Engineer will inform the Contractor in writing of his opinion, in which circumstances the Employer reserves the right to employ others to do the necessary work of reinstatement and to deduct the cost thereof as certified by the Engineer from any money due or which shall become due from the Employer to the Contractor.

The Contractor shall refer to the Employer without delay all claims, which may be considered to fall within the exceptions listed in the Conditions of Contract.

4.28 Protection of Existing Installations

The Contractor shall apply to the Engineer in writing at least 28 days before starting any work that involves interference with existing structures, equipment, etc at and around the site. The Contractor shall not execute such work until he has received permission to proceed, in writing from the Engineer.

The Contractor shall ensure that no earth, debris or rock is deposited on public or private roads or rights of way as a result of the Works and all vehicles leaving the Site shall be cleaned accordingly.

4.29 Protection of Existing Public and Private Services

The Contractor shall notify all public authorities, utility companies and private owners of proposed works that will affect them not less than two weeks before commencing the works.

The Contractor shall adequately protect, uphold, maintain and prevent damage to all services and shall not interfere with their operation without the prior consent of the public authorities, utility companies, private owners, or the Engineer as appropriate.

If any damage to services results from the execution of the Works, the Contractor shall immediately:

(a) Notify the Engineer and appropriate public authority, utility company or private owner.

(b) Make arrangements for the damage to be made good without delay to the satisfaction of the public authorities, utility company, private owner or Engineer as appropriate. The Contractor shall be liable for all costs for making good such damage.

The Engineer may issue instructions or make other such arrangements as he deems necessary, to repair rapidly any essential services damaged during the execution of the Contract. Such arrangements shall not affect any liability of the Contractor to pay for making good the damage.

4.30 Spare Parts

The spares shall comprise an adequate stock of the parts likely to be needed as routine replacements together with any major items or components which it may be desirable to hold in order to facilitate or expedite repair for a period of 24 months. The Contractor shall supply spare parts required for the continuous operation of the works during the period. The Contractor shall supply the details of spare parts and quantity required for the continuous operation of the plant for 2 years after the end of the project including O&M period. The Contractor shall supply the cost of the spare parts separately.

Spare parts shall be new and shall be packed separately from the main Plant in packages or containers designed to preserve the spares from the effects of long-term storage under the ambient conditions specified. Any items that cannot be packed in this way must be protected from corrosion by applying temporary protective coatings and shielded from mechanical damage. All items shall be clearly labelled with brief descriptions and part numbers.

4.31 Spillage and Leakage

Chemical preparing, dosing and transfer equipment shall be designed and arranged so that any leakage and spilling can be controlled and cannot enter ducts, channels, etc. and have a corrosive impact on pipes, cables or other equipment of the plant.

At all lubrication or greasing points grease trays or pans shall be provided to collect excessive lubricant or spillage onto the equipment or into water.

4.32 Special Tools and Appliances

The Contractor shall supply two complete sets of the special tools, lifting tackle, access equipment (ladders, scaffolding etc.) and greasing equipment necessary for the maintenance, repair, testing and overhaul of the Plant. The cost of all tools and test equipment shall deemed be covered under the O&M cost in the price schedule. The tools and tackle shall be handed over in fully working condition after completion of the project.

The Contractor will be permitted to utilise the overhead gantry cranes, supplied under this Contract for the purposes of installing the equipment in his supply. The Contractor shall be responsible for making all arrangements for the electricity supply to operate the cranes and for their service, maintenance and repairs. On completion of the installation the Contractor shall restore the cranes to as new condition by the replacement of all worn or defective components.

All special tools and test equipment necessary for overhauling the Plant and testing its performance shall be included and mounted in the warehouse at site with lockable doors. Racks and clips shall be provided for individual items with outline markings and labels to show where any equipment is missing.

4.33 Packing and Protection

Before any Plant is despatched from a manufacturer's factory it shall be adequately protected and packed to ensure that it will arrive on the Site in an undamaged condition. The methods employed for protection and packing must be suitable for withstanding the conditions which may be experienced during shipment, delivery to the Site and prolonged periods of storage, whether the items are shipped in packing cases, crates or only partially protected according to their nature.

Bright parts and bearing surfaces shall be protected from corrosion by applying a rust preventive lacquer, high melting point grease or similar temporary protection. A sufficient quantity of solvent shall be supplied with the plant to enable this coating to be removed on the Site. All machined flanges and other mating surfaces shall be protected by means of wood templates. The bolts for securing these templates shall not be reused in the final installation.

No one crate or package shall contain items of Plant intended for incorporation in more than one part of the Works. All items of Plant shall be clearly marked for identification against the packing list, which shall be placed in a waterproof envelope inside every packing case or crate. Every packing case and crate shall be indelibly marked to show its weight, serial number, top and bottom, shipping marks and handling instructions or sling marks.

Electrical Plant shall be enclosed in sealed airtight packages with dehydrating material, before being placed in packing cases on shock-absorbent material and secured by means of battens.

The RO system shall be packed, transported and stored at site as per the instruction of the manufacturer. The RO membrane should not be brought at the site and stored for long period of time. The membrane shall be dispatched to site with the approval of the Engineer and in accordance with the recommendations of the manufacturer. The RO membrane shall be kept at the site in the control environment as per the manufacturer's instruction so that the warrantee remains intact.

5. PARTICULAR CIVIL REQUIREMENTS

5.1 Introduction

The Standard Basic Specifications (SWRO Desalination Works Contract) issued by CMWSSB, set out the specifications that shall be followed for construction of general Works under the 400 MLD Chennai SWRO Desalination Project. In the event of any discrepancy between the provisions of the General Specifications and the Particular Specifications, the provisions of the Particular Specifications shall prevail over general specifications.

Contractor is responsible for the supply of all civil materials, machinery, marine equipment, supervision, labour, safety personnel and all expenses necessary for the installation of the structures that are part of the Contract. Nothing contained herein or missing shall be construed as relieving the Contractor of his obligation to provide a structure capable of performing its intended service for a submerged life as defined in the Contract. The Employer or its representatives reserve the right to inspect and reject at all stages of the Works when the manufactures are found not in compliance with the specification. Contractor shall give the Engineer and Employer's Representative full and unrestricted access to all areas of the work. The Contractor shall invite the Engineer and Employer's representatives for inspection after completion of the tasks prior to covering, coating/painting operations. They reserve the right to use still photography or video cameras to document visual inspection at any stage of work by the Contractor.

If any inspection or testing defined by or referenced in this Specification reveals that the work is non-compliant, then the entire preparation and application procedure shall be redone from the point where the Contractor can demonstrate compliance to the satisfaction of the Engineer. All remedial work shall be at the Contractor's expense to the satisfaction of the Engineer.

The Contractor shall be in possession of the current revisions and addenda of all codes, standards and specifications required for the Works. All such documents shall be made readily available to the Engineer or the Employer's Representatives upon request. Contractor shall employ only qualified and experienced personnel for the work. The Engineer/ Employer's Representatives shall determine the competence of personnel and shall retain the right to have replaced any Contractor's personnel if in their opinion, the proposed personnel are not working in accordance with Contract, approved procedures or plans.

The Contractor shall maintain all equipment in good conditions at all times and where necessary fully calibrated. The Employer shall inspect equipment and all deficiencies shall be corrected by Contractor at his sole expense and to the satisfaction of the Employer. Contractor shall maintain identification of every component and/or section of the pipe constituting the Intake and Outfall. These marks shall be recorded by the Contractor and the daily logs provided to the Engineer or Employer's site representative as requested.

All tests performed by the Contractor or his suppliers to prove materials characteristics shall be in accordance with the listed codes, standards and specifications or tests referenced herein and general civil requirements. In all cases, the Contractor is to get Engineer's written approval prior to the testing.

At the Employer's discretion, the Contractor shall be required to carry out tests to prove compliance of materials. All such tests shall be to Contractor's account. Contractor shall clearly state every exception to the requirements of this specification prior to Contract award, if no exceptions are stated full compliance should be confirmed.

Prior to award of the Contract along with the techno-commercial offer, the Contractor shall prove to the Employer his ability to install submarine pipelines, to perform the necessary underwater works fulfilling the requirements of this specification. After award of contract and before start of work, the Contractor shall submit a detailed written description of the procedures, materials, personnel, tests and safety measures for Engineer's approval. The description shall be accompanied by full details of the test results on similar works performed by the Contractor. The Contractor shall submit to the Engineer for review and approval of the following procedures:

- i) Construction and Project Management Plan
- ii) Site Organization Chart
- iii) Work Schedule and Progress Monitoring Plan
- iv) Quality Manual and Project Quality Plan
- v) Safety Execution Plan and Procedures
- vi) Installation Procedure and Manual
- vii) Utilization of Construction Equipment
- viii) Marine Operation Manual
- ix) Mooring Arrangements Procedure and Marine Spread Anchor Pattern
- x) Critical Lift study
- xi) Emergency and Medical Evacuation Plan

5.2 Scope of Civil Works

The scope under Civil Works includes complete structural designing, construction, procurement, installation, commissioning and 20 years operation and maintenance of the 400 MLD SWRO desalination plant on Design, Build and Operate (DBO) basis. The Works include all civil and all associated works required for construction of the plant with a sludge treatment and water recovery facility.

The following buildings/structures are part of the Works in scope along with all other civil works required to construct the 400 MLD SWRO desalination plant fully functioning as per the contract specifications and guarantees.

(i) Construction of complete Intake and Outfall works including intake/outfall pipeline, intake heads, intake well, pumping station etc. The scope includes the supply of all material, machinery, plant site, supervision, labour, safety personnel and all expenses necessary for the installation, testing and commissioning of the Intake and the Outfall system with all onshore and offshore works.

(ii) RCC Clear Water Reservoir of 9ML capacity along with structure for pumping station.

(iii) RCC Outfall Tank of about 4.5 ML capacity for wastewater discharge to the sea through diffusers.

(iv) Construction of RCC Sludge Balance Tank with pumping arrangement

(v) Construction of two Gravity Thickeners & Thickened Sludge Holding tanks with all associated structures.

(vi) Construction of Sludge treatment building (BFP building) with all associated structures.

(vii) Construction of Substation building including Switchyard & Transformer area

(viii) Construction of Administrative Building with all associated works.

(ix) Construction of Laboratory and Control room building

(x) Construction of large Workshop and Warehouse

(xi) Construction of all main and connecting roads and landscaping of the plant site area.

(xii) The following units/items shall be constructed separately for two plant streams of 200 MLD each.

a) Construction of inlet chambers and channel with baffles, flash mixing chamber, distribution chamber with weirs, walkway etc.

b) Construction of Flocculators & Tube Settlers tanks along with walkway etc.

c) Construction of Chemical Building with RCC solution preparation Tanks for coagulant and Polymer, Storage area, Bunds to collect splash chemicals, etc. and other features.

d) Construction of covered area for chlorination, acid and any other chemical storage tanks and dosing system.

e) Construction of DAF tanks covered along with walkway etc.

f) Construction of Gravity Dual Media Filters under Filter Building along with pumps, blowers areas and walkway etc.

g) Construction of RO Feed Tanks and other associated structures.

h) Construction of RO building along with CIP area, storage/maintenance areas and other allied structures etc.

i) Construction of Chemical Building for RO system to accommodate all chemical tanks and dosing system.

j) Construction of Permeate Tank and other associated structures.

k) Construction of Limestone Filters along with the Filtrate area, CO2 generation area, online Limestone makeup system and other associated structures.

l) Construction of metallic Product water tank of capacity 15ML along with other associated structures and piping.

m) Construction of covered Chambers for all valves, dismantling joints and flowmeters along with laying of all yard piping.

n) Construction of all MCC buildings

o) Any other civil construction to fulfil the requirements for the proposed plant as per the Contract.

5.3 Intake and Outfall Works

The intake system will be designed to have a hydraulic capacity of 1040 MLD. The intake conduit shall be of two number 2500 mm OD @ >7 bar HDPE pipe (SDR-21) and the outlet conduit shall be one number of 2500 mm OD 6.4 bar HDPE pipe (SDR-26) to produce 404 MLD permeate capacity. The waste seawater with high salinity will be discharge in the sea through nozzles to allow fast dispersion and less environmental impact.

Conventional dredging method is proposed to be employed for laying of Intake and Outfall conduits in the sea with minimum 1.5m cover over the pipe. The backfilling of the trench shall be done with the same excavated earth/material. The Spoil would be removed and returned to shore. The pipe would be prefabricated and floated over the trench or dragged along the trench. A safety boat shall be deployed in the vicinity to warn other craft to keep clear of the working area. Pipe shall be handled with care so as not to cause out-of-roundness of the pipe, damage to the ends, bending of the pipe etc. Excavation of the trench at the shoreline shall be executed in such a way to prevent damages to the shore structures. The trench shall be dredged to a depth from the sea bottom in order to give a vertical distance of 1.5 m (pipe top cover) between the top of the respective intake/ outfall pipelines and the surrounding natural undisturbed seabed level. The bottom of the trench shall be filled with a levelling fine sand bed having a minimum thickness of 200 mm to avoid any dent or puncture of the pipe due to hard pointed rock surface.

During excavation of the trench, all efforts shall be made by providing supports to protect the lateral walls from collapsing. Walls shall have a slope with a minimum inclination of 1:1 to maintain safety and to avoid any mishap. The trench shall be graded such that the minimum vertical radius of curvature of the pipeline does not generate excessive stresses in the pipeline. Any trench transitions for the pipelines (at spool pieces) shall be smoothly profiled back to the undisturbed natural seabed level so as to ensure that the pipeline is not subjected to over-stress while exiting or entering the trench. The bottom of the trench in a transition zone shall be at a constant smooth gradient providing a gentle continuous surface to support the pipeline.

Before start of the sinking process, the route shall be marked properly by buoys floating at sea surface. The Sinking of the pipeline shall be mainly carried out by nature's own forces i.e. gravity, buoyancy and air pressure while sinking of the diffuser, involves use of cranes. The sinking speed shall not exceed 0.3m/s. The compressor required for air filling in pipeline shall work up to 10 bar. The sinking shall be carried out in a continuous basis. The pipelines shall be equipped with blind flanges in each end. At the outmost end the blind flange is equipped with pipes and valves for air evacuation and air filling. The inmost blind end of the pipeline is also connected with valve and pipe for controlled water pumping inside the pipeline through pump during sinking. The air pressure inside the pipe shall be adjusted depending on the depth through the air valve and compressor to prevent any "run way". The sinking shall start by opening of the air valve in the outmost end carefully and controlling the inside pressure by a manometer if required to charge the pipe with compressed air and in no case the sinking speed shall be greater than 0.3 m/s. The sinking operation shall be continuous process. If for any reason, there is an interruption in the sinking operations, the reverse sinking process should start immediately by starting the compressor and must be completed within 15 minutes.

The sand backfilling can start when pipelines are laid and it is ensured that the extremities of the line at the intake chamber and spool piece end respectively remains free for the future connection to the onshore equipment and to the offshore intake screen installation. Backfilling shall be carried out using the native sand, restoring to the original situation. The backfilling shall be carried out in subsequent stages in order to allow the sand to be deposited duly compacted and to give, as final result, the original sea bottom configuration and water depth. The intake head and outfall diffuser section shall be connected to the main HDPE pipelines by means of appropriate pipe expansion spool pieces to be installed after the final positioning of the intake to suite levels. The sea bed characteristics of the area surrounding the Seawater Intake and the Outfall is generally constituted by loose sand with some areas of compact sand and some clay patches. The report comprising of the data & results w.r.t to offshore studies are enclosed with the Tender, Part-2 D-Site Data for reference. However, these studies are only indicative and the detailed investigations shall be carried out by the selected bidder (Contractor), as required before execution of works to confirm the data and to meet the contractual requirements.

The scope of the Contractor for intake and outfall system includes but is not limited to:

- Contractor will be responsible of the supply of material, machinery, marine equipment, supervision, labour, safety personnel and all expenses necessary for the installation of the structures part of the Contract.
- Carryout all the onshore and offshore studies and surveys of the area including bore logs to verify the nature of the sea bottom for construction of marine works.
- Excavation of the appropriate trench in the sea bottom with appropriate equipment and supply and receive the HDPE pipes along with associated accessories constituting the intake and the outfall.
- Backfilling of the trench, supply and installation of the various materials in the areas for construction of sea water intake and outfall along with pipe conduits.
- Supply, welding, laying and connection of two High Density Polyethylene (HDPE) intake pipes > 6.5 bar and one HDPE outfall pipe 6.4 bar in the submarine trench in accordance with the specifications.
- Prefabrication and installation of concrete/anchor blocks for the anchorage of the pipes. The blocks shall be manufactured with Portland Slag cement.
- Prefabrication and installation of the concrete blocks for the system towards protection

against trawling fishing and other possible causes of damage.

- Fabrication and installation of the intake heads and GRP intake screens at the extremity of the sea water intake pipeline and connection of the pipeline with special expansion spool piece joint as required.
- Provision for pigging to clean the pipelines and pig launching station and landing (collection) point suitable for the purpose shall be provided.
- Fabrication and installation of the HDPE reject outfall diffusers section and connection with special expansion spool piece joint as required.
- Supply and installation of the necessary Navigational Aids like buoy with red lantern marks to mark the position of the structures as per drawings.

The decoded and validated digital data shall be supplied by the Contractor to the Employer through email transfer and also on USB. The information shall be on the Longitudinal profile and Event data. The Longitudinal profile shall include the KP along the theoretical design route, sea bottom depth along the pipe axis, Pipe depth, Easting and Northing coordinate and any other related information. The Event data shall include the KP along the theoretical design route, Event code and event description. These files shall be delivered before post trenching activities survey.

5.3.1 System Description

5.3.1.1 *Seawater Intake*

The sea water intake facilities cover two seawater intake heads with screen offshore and two intake pipes to bring water to intake well and pumping station onshore. The offshore units comprise of sea water intake system comprising of intake suction head fitted with 100 mm c/c GRP screen along with ring provision of Hypo dosing and air bursting arrangement along the periphery of the offshore intake screen. Nylon net, two concrete intake head and associated pipelines. The net shall be properly anchored and shall have provision for easy replacement. The intake structure (Head) shall be prefabricated in one single piece and shall be installed using the preapproved procedure.

The seabed conditions are one of the primary factors in determining the location of seawater intake and outfall conduits. A 100 mm c/c opening screen in GRP construction shall be provided at the intake to exclude larger marine life. The said screen shall be designed with an approach velocity of ≤ 0.12 m/s to minimise the entrapment of marine species. A fish net with will be provided to minimise the ingress of jelly fish to the intake. The fish net will be required to be inspected and replaced from time to time, as the same is likely to be damaged by marine lives. The head loss through the intake system will also be monitored, and in any increase in system losses indicating fouling at the intake, or the growth of biomass within the intake conduit, the same shall be cleaned through divers. The Hypo dosing lines and compressed air line shall be of HDPE material per IS 4984 with possibly GRP cover to protect the pipe and shall be laid along the intake pipe properly clipped at the crown of the pipe. The length of the intake conduit is not defined at present, the preliminary study proposed that the intake pipes should be laid up to a distance of approx. 1800 m offshore, the depth at the intake would be about 12 metres at low tide. The bidder should cost the intake system based on this length and provide the cost per running m. Because the grade on the seabed flattens, there is not much advantage in seabed depth by increasing the length from 1,000 m @ 10m depth to 1800m @ 12m depth. Depending on the bathymetric and brine dispersion studies conducted by the Contractor and approved by the Engineer, the final decision for the intake pipe length shall be made within 1000m to 1800m. As much as feasible, all the pipelines - two intake and one outfall, shall be laid in the same trench or adjacent to each other on the same alignment to avoid the movement of the heavy machinery and repetition of the works.

5.3.1.2 *Reject Outfall*

An outfall shall be one 2500 mm OD 6.4 bar HDPE pipe conduits. Coastal currents flow from south to north from August to October and from north to south from November to March each year. The currents from the South to the North are stronger than the currents from the North to the South. For this reason, the outfall will be located to the North of the intake, as same at existing Nemmeli plants. Since the near shore currents in this region are predominantly directed towards North, it is preferred to locate the outfall on the Northern side, so that the plume spread would be mostly oriented towards North and there would not be any re-circuit to the intake. Sea water outfall pipe shall be High density polyethylene pipe (black). The length of the outfall conduit is not defined at present, the preliminary study proposed that the outfall pipes should be laid up to a distance of approx. 1000 m offshore about 600 m apart from intake head. The bidder should cost the outfall system based on this length and provide the cost per running m. Depending on the bathymetric and brine dispersion studies conducted by the Contractor and approved by the Engineer, the final decision for the outfall pipe length shall be taken within 700m to 1800m.

5.3.1.3 *HDPE Pipes*

Contractor shall supply the HDPE pipes (PN 21) as per IS 4984, shall keep them in custody in a safe and protected area, shall check all pipes for damage, dents, out of roundness, gouges and flat ends etc. All damage and other defects noted shall be recorded by the Contractor and witnessed by the Engineer/ Employer's representatives. Damage caused to pipe whilst in the custody of the Contractor shall be reported to the Engineer and repaired by the Contractor to the satisfaction of the Engineer. The cost of such repair work and the cost of any material lost shall be at the Contractor expense. The history and details of each pipe, including the pipe identification number shall be recorded by the Contractor before the commencement of installation and a unique cross reference number shall be painted by the Contractor on the inside and outside of the pipe on both the ends. All documents related to the pipes shall be preserved by the Contractor for inclusion into the final certification documents.

5.3.1.4 *Pipe Handling*

HDPE pipes shall be handled at all times in a manner, which avoids damages. All pipes shall be lifted clear and moved without being dragged over the ground or any obstructions. Alternate lifting equipment or specially manufactured lifting hooks may be permitted after approval has been given by the Engineer and under the supervision of the pipe manufacturer. Pipes shall not be rolled or dropped. Line pipe shall be positioned with care so as not to cause out-of-roundness of the pipe, damage to the ends, bending of the pipe etc. Any pipe suffering impact damage during handling shall be immediately quarantined and the Engineer/ Employer's representative be advised for their inspection and eventual subsequent acceptance and/or repairs. Excess damage beyond the repair will be assessed by the Engineer/ Employer's representative and shall be rejected. The rejected pipe shall be removed from the site by the Contractor immediately. Lifting equipment shall be approved by the Engineer. Wire ropes alone shall not be used to lift pipes. Where fork lift trucks are to be used to transport the pipe, they shall be suitably padded to prevent damage. All pipe handling equipment and procedures shall be subject to the approval of the Engineer prior to their use.

5.3.1.5 *Pipe Stacking*

Bare pipe shall not be stacked more than two layers high. The pipe shall be stacked, either on properly constructed and maintained pipe racks, inspected and approved by the Employer, or on a minimum of two coal tar enamel covered loose graded sand windrows. The sand windrows shall at least be 15 cm deep and not less than 2 m wide (each), approximately 7 m apart, and shall not be separated by bearers. Contractor shall submit proposed stacking arrangement, including stacking heights pipe end supports and stacking surface to the Employer for approval, prior to use and installation. If the Contractor requires to stack the pipes in a different number of layers, he shall submit to the Employer all relevant calculations certifying the new proposed configuration.

End supports need to be placed at either end of the stack to prevent to pipe joints from rolling. If pipes are to be stored for an extended period, precautions shall be taken to prevent damage of pipe ends and interiors. The pipe shall be carefully lowered to prevent impact damage and stacked in such a way that water and mud cannot accumulate within the pipe.

5.3.1.6 *Concrete*

Cement, sand, aggregate for concrete works shall be as per the enclosed General Civil specifications of the bid document and in case of conflict between the General Civil specifications and the guidelines mentioned in Particular Civil works, the Particular Civil specifications shall prevail. The concrete blocks to be installed for the support and ballast of the Outfall diffusers and Intake screen, for the cast in situ inside the prefabricated caisson at the elbow of the Intake pipeline and for the anti-trawl fishing protections, anti- buoyancy saddles for intake and outfall pipeline as per the span & load mentioned in the respective intake and outfall pipeline construction drawings shall be of the type for underwater marine seawater environment construction and shall be dense concrete not less than M40. The concrete shall be suitable for marine installations and cement used shall be resistant to sulphate and chloride attack under submerged seawater conditions.

5.3.1.7 *Cement*

Sulphate resisting Portland cement conforming to BS 4027 or better shall be used. Cement shall be suitable for use with seawater and shall have a Tri-Calcium Aluminate (C3A) content of not more than 3.5% and an alkali content of less than 0.6%. All cement batches shall be covered by manufacturer's test certificates which shall be submitted to the Engineer. These shall cover the physical and performance characteristics of the cement. Cement shall be stored in such a way that provides satisfactory protection from ambient elements. Cement that has hardened, become partially set or has become lumpy shall be rejected and removed from the site by the Contractor.

5.3.1.8 *Sand*

Sand used for concrete coating mix shall be silica type conforming to BS EN 12620 and shall be well graded from fine to coarse grains.

5.3.1.9 *Crushed Stone*

Crushed stone shall be clean and free from any chemicals or soils or organic material that could impair the concrete strength.

5.3.1.10 *Aggregate*

Mix Grading Aggregate mix shall be clean and free from injurious amount of clay, salt and alkali, organic or other deleterious material and should satisfy the code IS-2386 (Part IV)-1963. Alkali compatibility is essential for aggregate. The Contractor shall maintain a material traceability system to record properly the receipt, return or disposal of all materials supplied and their location within the coating yard on a real-time basis. The Contractor shall permit inspection of these records by the Engineer/ Employer's representatives at any time.

5.3.2 **Installation Specification**

5.3.2.1 *Shore Approach Preparation*

Contractor shall reclaim and prepare the Site where he intends to constitute the yard for the assembly and preparation of the structures. He is responsible for the construction of the required access roads and the installation of all services relevant to the Works. The start of the excavation of the trench at the shoreline shall be executed in such a way to prevent damages to the shore structures and appropriate sheet pile walls shall be installed (if necessary) to avoid that the action of the waves can cause difficulties to the works carried out by others onshore. The pipeline trench would be dredged using an air lift pump, dragline or clamshell, or excavated with a long armed back hoe from a jack up barge. If rock is present, underwater drilling and blasting may be required. Spoil would be removed and returned to shore. This activity would create significant stirred sediments and may require the use of temporary curtains to contain the turbidity plume. Stone bedding material would be imported and placed at the bottom of the trench. The pipe would be prefabricated and floated over the trench or dragged along the trench with neutral buoyancy before being sunk progressively into position by the release of air. Stone pipe surround would then be placed from a barge using chutes and divers and rock protection lowered and placed as trench backfill. The size of the rock protection shall be decided upon the wave climate and depth and the seabed to its original profile and allows longshore drift to remain unaffected in the long term.

5.3.2.2 *Pre-Work and Pre-Lay Site Survey*

The Contractor shall carry out a pre-works survey to confirm that the site conditions, including sea bottom profile, are the conditions described as per the bathymetries and side scan supplied by the Employer. Contractor is responsible to highlight to the Engineer any eventual discrepancy with the original data and all eventual variations due to a lack in the execution of this survey and communication to the Employer shall not constitute origin for any claim whatsoever. Prior to trenching operations, Contractor shall ensure that the pipeline is not subjected to excessive spanning as per the requirements of specific Standards. For that purpose, Contractor shall conduct a post-lay survey using divers and/or ROV depending on the work area. Accordingly, Contractor shall propose procedures for the trenching equipment to negotiate areas of pipeline spanning (if any) such that the pipeline is not over-stressed. Prior to mobilizing for the trenching activities, the Contractor shall review soils data along the pipeline route to ensure the adequacy of the proposed trenching method and that no adverse conditions, which could affect the trenching operations efficiency, are anticipated well in advance.

5.3.2.3 *Trenching Method*

The Contractor shall propose its preferred method(s) for trenching the pipeline taking into consideration the involved soils and seabed features along the proposed offshore route. A preliminary study of the bathymetric survey has been included in the tender Part-2 D-Site Data. The proposed method shall include procedures for negotiating seabed features, the direction of trenching, trenching sequence and split and the entire trenching methodology shall be established by the Contractor in conjunction with the Engineer/ Employer's representative to guarantee efficient operation of the trenching spread.

5.3.2.4 *Trenching Requirements*

The Contractor shall proceed with the excavation of the trench of the 2500 mm OD, subsea pipeline taking into consideration the following:

Contractor shall dredge the trench to the required depth from the sea bottom in order to give a vertical distance of 1.5 m (pipe top cover) between the top of the respective intake and outfall pipes and the surrounding natural undisturbed seabed level. The top shall be accounted from the crown of the pipe.

- Lateral walls of excavation shall have a minimum slope characteristic of the sea bed to prevent collapse of trench.
- Contractor shall maintain a maximum trench out-of-straightness "OOS" of 0.25 m all over the route in order to mitigate upheaval buckling in case of natural backfilling.
- Pipe should not be lowered until the trench is of the desired width. Any pipeline portions not satisfying the above mentioned "OOS" value shall be adequately corrected in accordance with Contractor procedures and at his sole expense.
- The bottom of the trench shall be compacted and filled with a levelling fine sand bed having a minimum thickness of 0.2 m. Eventual material protruding out of this layer shall be duly recorded and the Engineer shall be informed to agree with the Contractor for the necessary remedies.
- The shape of the trench shall be always in control of the Contractor and designed section shall be restored when and if necessary, at the sole expense of the Contractor.

If, during trenching operations, Contractor encounters obstacles (not likely), he shall at his own expense and to the satisfaction of the Engineer, immediately cease trenching operations on that portion of the pipeline and report to the Engineer the details of the obstructions along with his recommended solution. Any obstacles such as boulders or wrecks, preventing trenching the line shall be removed by the Contractor.

5.3.2.5 *Trench-Out of Straightness- Survey (OOS)*

As soon as possible after completion of trenching operations, Contractor shall conduct a post-trenching survey to determine the out-of-straightness of the pipeline and ensure that it does not exceed 0.25 m for the entire route. Contractor shall acquire, record and map all necessary data required to determine the "Astrenched" position. Contractor shall perform imperfection out of straightness "OOS" surveys, which shall constitute the basis for "OOS" Assessment, to ensure that the required cover depths for the two intake and one outfall pipelines are maintained along their route. The required "OOS" survey should accurately define the pipeline profile after completion of trenching operations. Prior to the "OOS" survey, repeatability trials should be undertaken to assess the accuracy of the OOS measurements.

5.3.2.6 *Trench Grading and Profile*

The trench shall be graded such that the minimum vertical radius of curvature of the pipeline does not generate excessive stresses in the pipeline. Any trench transitions for the pipelines (at spool pieces) shall be smoothly profiled back to the undisturbed natural seabed level so as to ensure that the pipeline is not subjected to over-stress while exiting or entering the trench. The bottom of the trench in a transition zone shall be at a constant smooth gradient providing a gentle continuous surface to support the pipeline. Unsupported pipe spans caused by trenching (despite being unlikely) shall not be in excess of the maximum allowable free span lengths given in the relevant standards. Unsupported pipeline spans greater than the allowable span lengths shall be corrected by the Contractor. The Contractor is required to adjust the bottom profile of the excavation in the eventuality that the onshore civil works contractor has to modify the elevation of the Intake chamber of the desalination plant. In this case the slope of the trench shall smoothly be modified in accordance with the final defined elevation. For the Outfall line there is no necessity to modify the sea bed profile during trenching but only make the necessary adjustment to the spool piece at tie-in point.

5.3.2.7 *Levelling Sand Bed*

The Contractor shall describe in detail the method he intends to use for the distribution of the fine sand in the bottom of the trench in order to have a perfectly levelled and smooth surface. Contractor shall provide, at his own expense, to the correction of any eventual differences in level of the fine sand bottom trench bed.

5.3.2.8 *Sinking of Submarine HDPE Pipeline*

The specifications below deals with the sinking process and necessary precautions to be taken to secure a safe installation of pipeline at the bottom. Sinking of the pipeline is mainly carried out by nature's own forces i.e. gravity, buoyancy and air pressure.

During sinking of the intake and outfall pipeline, the following factors shall be taken into consideration:

a) Detailed sinking procedure must be worked out including technical parameters, necessary resources, communication systems and emergency procedures.

b) Detailed calculations of the sinking curvatures must be carried out by computer programs.

c) The pulling force in the end shall be calculated and minimum shall be 40 tons. Necessary equipment should be arranged for the same.

d) The sinking speed shall not exceed 0.3m/s.

e) The compressor required for air filling in pipeline shall work up to 10 bar. Air pressure curve as a function of depth shall be calculated.

f) The critical radius of curvature is to be determined for outfall and intake pipeline.

g) The sinking shall be carried out in a continuous basis.

h) Concrete weights must be fixed securely.

i) The weather conditions must be satisfactory.

j) The diffuser and intake head must be installed as a beam system by use of cranes.

k) The static system during lowering of the intake head and diffuser must be calculated.

l) The intake screen head and diffuser must be 'mated' to the main pipeline at sea bottom (in the trench) with the special spool joint.

m) The sinking shall be carried out under assistance of experience personnel in this field.

n) Use of divers shall be minimised and minimum possible work related to installation must be carried inside the sea.

o) The pipe string will be towed from the production area by tugboats to the installation site. The Contractor shall prepare a detailed sinking procedure before installation.

The concrete weights shall be fixed to the pipeline at the prescribed centre to centre distance. The weights can be installed onshore or offshore. The concrete weights shall be fixed properly to prevent sliding during installation. To increase the co-efficient of friction and to avoid scratches in the surface of pipe, an EPDM rubber gasket between the pipe and concrete weights shall be fixed. When all the pipe sections are fitted together, the pipeline is ready for sinking process. The pipeline is equipped with blind flanges in each end. At the outmost end, the blind flange is also equipped with pipes and valves for air evacuation and air filling.

Before start of the sinking process, the route shall be marked properly by buoys floating at sea surface. Particular care should be taken for the weather forecast as very little wind and waves should exist during the sinking process. The entire pipeline shall be positioned in the correct route by boats, barges and small boats.

The inmost blind end of the pipeline is also connected with valve and pipe for controlled water pumping inside the pipeline through pump during sinking The air pressure inside the pipe shall be adjusted depending on the depth through the air valve and compressor to prevent any "run way".

The calculated pulling force must be applied in the outmost end (end near shore) of the pipe before the sinking starts. This force can vary during the sinking operation and shall be specially calculated beforehand.

The sinking starts by opening of the air valve in the outmost end carefully and controlling the inside pressure by a manometer if required to charge the pipe with compressed air. The Contractor shall before starting the sinking operation will prepare the curve showing the necessary air pressure as it is the function of sinking depth. The sinking speed shall be a controlled speed and shall not exceed 0.3 m/s.

All precautions should be taken to avoid buckling of pipe section. The sinking operation shall be continuous process. If for any reason, there is an interruption in the sinking operations, the reverse sinking process should start immediately by starting the compressor and must be completed within 15 minutes.

When the sinking reaches the outmost end of the pipeline, the S- configuration will transform to J-configuration and at this position, very precise and correct pulling force and sinking speed shall be applied to prevent dynamic acceleration forces when the last volume of air leaves the pipe. 50% of the pipe length, without water should be able to sink during launching. Hence proper anchorage should be done.

5.3.2.9 *As-Lowered Survey (Post-Trench Survey)*

As-lowered survey shall be conducted in order to meet the following objectives:

- To provide all relevant documentation necessary to demonstrate and to prove that the pipelines have been lowered in accordance with the acceptance criteria.
- Video inspection of the physical condition of top and sides of the As-lowered pipeline for detection of possible damage, pipeline suspensions, etc.
- Determination of As-lowered pipeline position.

5.3.2.10 *Anti-Trawl Barriers for Intake and Outfall*

Within the Scope of Work of this project is the installation of about 50 nos. 2.50 x 2.50 x 1.50 m anti-trawling fishing concrete blocks in two concentric lanes having origin in the centre of the two Intake structures. Also, similar anti-trawl fishing protection zone shall be provided around diffusers. The external protection barrier of blocks is connected by a nylon net 0.02 dia. 10 mm sq opening of an approximate growth of 250 m. The installation of these concrete blocks shall be carried out at the real end of the construction, when the Intake/outfall structure is installed by using the crane of the installation barge with the assistance of the underwater equipment.

Any different solution in the installation proposed by Contractor shall be approved by Employers representative.

5.3.3 Inspection

Contractor shall perform stage wise inspection and testing of all equipment/material used to carry out the survey work and the same shall be witnessed by Engineer/Employer's representative. Certified test reports of the instrument used shall be provided. Contractor shall carry out onshore pressure testing (hydro testing) of the intake and outfall pipeline at 1.5 times the rated pressure prior to marine installation of the pipelines. Hydrostatic testing of the system should be carried out as per IS-7634 – 1975/ equivalent European standard. Contractor shall provide a means of remotely monitoring the trenching operations. A full video record of trenching operations shall be obtained and submitted to the Employer. The operations observed will depend on the trenching equipment being used. Trenching shall proceed only when video monitoring is available. Contractor shall continuously monitor the status of trenching operations, the lowered depth of pipe and the position of the pipelines in the trench to ensure satisfactory performance of the equipment being used.

5.3.4 Diving or ROV Reporting

As part of the trenching spread, Contractor shall provide an experienced Diving team and/or the Remote Operating Vehicle (ROV) with all required facilities to perform the Scope of Work. Facilities for continuous video monitoring of trenching machine operations shall be provided. VHS (Video Home System) recording facilities including sufficient tape supplies shall be provided to record all video pictures. During the trenching operations, Contractor divers or ROV shall periodically report to Employer at least once every 24 hours on the operation of the trenching machine. This check shall be increased to every 8 hours after the initial start-up for the first 24 hours. The performance report for information about the condition of the pipe and joints, depth and profile of trench and video inspection back-up shall be provided every day through email.

5.3.5 Pipe Laying

Laying of the Intake and Outfall pipelines is expected to be with the "Bottom Pull" system carried out by an appropriate pulling barge equipped with a suitable pulling winch. The two accessories approx. 100 mm dia. hypochlorite and 100 mm dia. compressed air respectively submarine pipelines can be laid simultaneously with the main 2500 mm OD HDPE pipeline. In this case the intake line shall be firmly anchored to the sea bottom and natural backfilling so that the current and/or storm shall always be under control and not disturb the pipeline. With the utilization of the above system the Contractor shall be responsible to prepare a suitable area onshore for the transportation, storage and assembly of the pipeline strings. Contractor shall submit to the Employer, for approval, a detailed layout of the Site including the description of the sources of power, water, aggregates etc. he intends to utilize for the Project.

If Contractor intends to utilize a different system of laying, he may be allowed to do so but shall propose the alternative procedure to the employer for their approval. The proposed procedure for installation shall describe in details about the methodology and equipment required for Employer's review and approval. In any case, the Contractor shall deliver to the Employer the full description of the marine equipment proposed to be deputed for the execution of the marine operations clearly indicating whether the equipment is owned, hired or at a temporary disposal.

5.3.6 Backfilling

5.3.6.1 *Intake Pipeline*

Once the entire offshore length of intake pipeline has been laid and the final position controlled by positioning system is assured, the sand backfilling can start ensuring that the extremities of the line at the intake chamber and spool piece end respectively remains free for the future connection to the onshore equipment and to the offshore intake screen installation. Backfilling shall be carried out using the natural original as backfilling material sand, restoring to the original situation. Contractor shall take due care during backfilling that together with the fine sand, coarse material that can damage the Intake pipe is not used. Measurements of the backfilling shall be continuously under control of the Contractor and report and diagrams of the profile submitted daily to the Employer. The backfilling shall be carried out in subsequent stages in order to allow the sand to be deposited duly compacted and to give, as final result, the original sea bottom configuration and water depth.

5.3.6.2 *Intake Structure Area*

After the installation of the Intake structure and its connection to the HDPE submarine pipeline with special spool piece, the area surrounding the Intake structure shall be covered by a layer of approximate weight of stones of 5-100 Kg size up to minimum 2 m below the natural sea bed level. On top of this small size stones layer, another layer 1.0 m thick of 250-500 Kg stones shall be installed. The area covered by these two layers shall have a diameter of 50 m having origin in the centre of the Intake screen structure (Intake Head). Nylon net shall be installed all around with floating buoys.

The structure must be modelled in order to establish the structural dimensions, so that it is able to support the forces generated by the calculated force actions. The concrete structures, the piece shall be reinforced, and it is recommended to construct a finite elements model, this is because, very often, it is intended that the structure has a significant weight, and accordingly the concrete walls and base plates have significant thicknesses. The structure/tower/head should be anchored to the hard strata below the sea bed level and the area around that shall be filled with gravels. The vertical height in 1:3 from bottom of sea bed to the 300 mm level below the screen should be graded with gravels to prevent intake of sea bed turbulence sediments in the plant.

5.3.6.3 *Outfall Pipeline and Diffusers Area*

Similarly, the backfilling operations for the entire length of Outfall pipeline, shall be carried out by Contractor in order to return to the original configuration of the seabed. The area where the diffuser's manifold has to be installed, having approximate dimensions of 70 x 15.0 m and a thickness of 2.0 m average, shall be covered by a layer of 200-500 Kg stones. This may be changed after proper calculation to be carried out by the Contractor.

5.3.6.4 *Outfall Diffusers Installation*

The Outfall diffuser is constituted by a HDPE manifold 2500 mm OD of an approximate length of 150 m and having about 30 nos. internal dia 350 mm HDPE pipe diffusers inserted with an angle of 50° in respect of the upper tangent of the pipe. This is an indicative design information. Additional simulations for brine dispersion will be done by the Contractor to fine-tune the diffuser location and arrangement. All diffusers are blind flanged and flanges shall be removed by divers after the installation of the Outfall and Intake is completed.

5.3.7 Contractor Equipment, Personnel & HSE Requirement

5.3.7.1 *Equipment*

Contractor shall furnish complete details of the machineries to be deployed for the trenching spread capable of working in the involved water depths, seabed conditions and environmental conditions. Contractor trenching equipment and its operation shall be such that the pipelines and their joints do not sustain damage. Contractor shall present all design and operation calculations demonstrating that the machine is appropriate, safe and efficient for the trenching works. Documentation shall include results of all field trials, including description of location, soil types and trenching performance.

5.3.7.2 *Support Machinery*

All vessels required for carrying out of the Scope of Work shall be in full working order and in good conditions. Contractor shall provide to Client descriptions and technical information on all proposed trenching vessels. The vessel used for the works shall have the following characteristics:

i) Ensure a good operating stability.
ii) Have installed a suitable capacity for the job requirements crane.
iii) Satisfy international safety rules applicable in the work area.
iv) Have all the permits required to operate in the work area.
v) Hold certificates issued by Lloyds or Bureau Veritas or others.
vi) Ensure suitable board and lodgings for 2 Employer's technicians.
vii) Radio equipment with frequencies for establishing reliable links with local radio stations.
viii) Allow suitable space with the necessary equipment and facilities for divers' activities.
ix) Provide a workshop for instrument maintenance.
x) Allow suitable space for the installation of the Data Acquisition System and Data Processing equipment.
xi) Provide air-conditioned working areas.

The contractor shall be fully responsible to complete the contract as per requirements with at most safety and meeting the environmental regulations.

5.4 Inlet Structure

The Inlet system including feed channel, chemical dosing, pre-chlorination, and rapid mixing shall be of reinforced concrete construction in CC mix M35. The chamber shall have the concrete stairs and a 1m wide walkway along the length and across the width to allow operation and maintenance of the system with hand railing of SS316 on all the peripheral length, and reinforced concrete staircase.

5.5 Chemical Buildings

Three Chemical building shall be provided for the pre-treatment, the RO system including CIP chemicals and for the post treatment.

The pre-treatment chemical building shall have 3 portions or fully separate structures. One portion of the building shall be assigned for Ferric Chloride and Polyelectrolyte preparation and storage. Other two portions shall be assigned for Chlorination and Acid storage and dosing system.

The RO Chemical building shall be built near RO building, which will inhouse all chemical tanks and dosing system for RO trains and CIP system. The post-treatment chemical building shall inhouse caustic and hypochlorite storage and dosing system.

Adequate space shall be provided for storage, preparation and dosing of the chemical solution. The building should also have 1-3 ton EOT as needed to move the pumps, motors and agitators for installation and maintenance. The details of the tanks and dosing system are provided in the Part-2 Section VI, A3 Particular Process Requirements.

Separate and adequate vehicle approaches shall be provided for each portion of the building. The chemical building shall have sufficient ventilation as per the requirements given elsewhere. Sufficient stairs and walkway with hand railing of SS316 shall be provided to inspect the agitators and inside the chemical tanks. A covered reinforced concrete service water storage tank (minimum 2 hours capacity at maximum consumption) shall be constructed on the roof of each chemical building for chemical preparation and chemical inline dilution and line flushing as needed. A toilet attached to the chemical building shall be constructed as per the specifications in the tender document.

5.6 Flocculator & Clarifier with Tube Settlers

The Clariflocculator with Tube settler shall be of reinforced concrete with access from two ends and walkway facilities for maintenance and inspection. The structure shall be constructed in RCC mix M35 as per the requirements for structures in contact with seawater. Drainage of flocculation tanks and tube settlers shall be from each hopper including back flushing system for cleaning purposes with manual valves. There will be a magnetic flowmeter and an auto operated knife valve with remote sensors in the common header of sludge from flocculators and also in the common header of sludge from tube settlers. The clarified water from tube settler will be fed to the DAF. There is a bypass line which circumvent the DAF unit and directly feeds to the Filter inlet channel.

5.7 DAF and Filter Building

DAF and Dual Media Filters shall be housed in reinforced concrete building with access from two ends and sufficient walkway facilities and space for maintenance and inspection. The structure shall be constructed in RCC mix M35 as per the requirements for structures in contact with seawater. There shall be sufficient ventilation and glass windows with steel mesh to prevent birds entrance in the building. Details of the DAF and Filters have been provided in the Part-2

Section VI, A3 Particular Process Requirements.

5.8 RO Building, Warehouse and Workshop

The RO building, warehouse and workshop shall be steel structures. Design of structure shall be based on the dead and live load requirements of the structure as it will be built. Snow, wind, and seismic loads shall be considered where they are applicable. Racking must be built stronger and be better braced. The structural design process will involve the steps of i) calculating the permanent actions and determining the variable actions, ii) identifying the load paths that carry the applied actions (vertical and horizontal) to the foundations and, iii) selecting preliminary sizes for the members.

All nuts and bolts and fasters shall be of stainless steel and all other steel items shall be hot galvanised. All steel beams and columns shall be polished and epoxy painted. For the roof and wall panel shall be steel sheets (PU sandwich panel). The door and window of the steel frame structure can be made of aluminium alloy. There will be sufficient fixed glass windows at roof and wall to lighten inside the building. There shall be sufficient crane runway beam designed according to your overhead crane parameter and EOTs of the required load bearing to meet the requirement.

RO building (Industrial Steel structure) will inhouse all RO skids, CIP system, RO flushing pumps and all system associated with RO system.

The warehouse and workshop shall be adjacent buildings of minimum area 80m x 40m and 50m x 40m respectively. Both the building shall have all features and facilities required for the purpose.

The details of the Workshop and Warehouse are given in the Annexure A5-1

5.9 Limestone Filter

The Contractor shall provide reinforced concrete building for Limestone filter with access at the top of the filter. The structure shall be constructed in RCC mix M35. Details of the Limestone filter has been provided in the Part-2 Section VI, A3 Particular Process Requirements.

5.10 Water Retaining Tanks

All water retaining tanks such as Intake well, RO feed tank, Clear water tank, Sludge balance tank, Sludge holding tank, Outfall tank and other tanks shall be of reinforced concrete M-35 with access and walkway facilities as described elsewhere. All tanks where needed, shall overflow to the Outfall tank for discharge to the sea.

5.11 Sludge Thickener & Pump House

The sludge shall be pumped from the sludge balancing tank to gravity sludge thickeners and dosed with polymer to assist the thickening process. Two gravity thickeners shall be provided. The thickener tanks shall be of reinforced concrete (M-35) construction. The tanks shall have a sloping bottom with central hopper. The circular tank shall have a peripheral weir and collecting channel. Other facilities such as an access bridge to centre rotating scraper, walkways and stairs to ground with SS316 hand railing shall be provided as described elsewhere. The supernatant from the sludge thickeners shall flow by gravity to the Outfall tank.

5.12 Sludge Dewatering Building

The sludge dewatering building shall be a two storied structure. The polymer feed systems, belt filter press feed pumps, belt wash water pumps and chemical dosing system should be located on the ground floor of this building. The belt filter presses and electrical room should be located on the first floor of this building. The building should have necessary staircases. There shall be an intermediate platform along a conveyor belt below the first floor. Chutes shall be provided for discharging dewatered sludge cake into the trailer. Necessary foundations shall be provided for the BFPs. The floor slabs on which the BFPs are positioned shall be designed to account for the loadings from the BFPs in the event of the BFP vibration dampening equipment failing. A covered reinforced concrete service water storage tank shall be mounted on the roof of the sludge dewatering building. A toilet shall also be provided in the sludge dewatering building.

5.13 Substation Building

The construction of new substation buildings as essential including switchyard and transformer area shall be constructed with RCC framework looking to the space requirement. Suitable fencing shall be done of transformer area.

5.14 Administrative, Control Room and Laboratory Building

Two buildings shall be constructed – one for the administrative works and another for the plant control room plus the laboratory. The administrative building shall be G+2 story building. While a G+1 story building shall be constructed to locate the plant control room at the ground floor and laboratory at the first floor. An indicative plan of the building floors has been provided in the Part-2 Section VI, C Drawings.

5.15 Design Submissions

Complete detailed design calculations of foundations and superstructure together with general arrangement drawings, architectural drawings, reinforcement drawings and other drawings shall be submitted to the Engineer /Employer's representative. Separate design calculations for foundations and superstructures submitted independent of each other shall deemed to be incomplete and will not be accepted. The design considerations described hereunder establish the minimum basic requirements of plain and reinforced concrete structures, masonry structures and structural steel works. However, any particular structure shall be designed for the satisfactory performance of the functions for which the same is being constructed. The Contractor shall also take care to check the stability of partly completed structures.

5.16 Design Standards

All designs shall be based on the latest Indian Standard (IS) Specifications or Codes of Practice. The design standards adopted shall follow the best modern engineering practice in the field based on any other international standard or specialist literature subject to such standard reference or extract of such literature in the English language being supplied to and approved by the Engineer.

In case of any variation or contradiction between the provisions of the IS Standards or Codes and the specifications given along with the submitted tender document, the provision given in this Specification shall be followed. All the reinforced concrete structural designs shall generally conform to the following publications of the Indian Standards Institution:

IS:456	Code of Practice for plain and reinforced concrete
IS:875	Code of Practice for design loads for buildings and structures (Part I to V)
IS:3370	Code of Practice for concrete structures for the storage of liquids (Part I to IV)
IS:1893	Criteria for earthquake resistant design of structures (Part-1)
IS:2974	Code of Practice for design and construction of machine foundations (Part 1 to 4)
IS:13920	Ductile Detailing of Reinforced Concrete Structures subjected to Seismic forces- Code of Practice

All structural steel design shall generally conform to the following publications of the Indian Standards Institution:

IS:800	Code of Practice for general construction in steel
IS:806	Code of Practice for use of steel tubes in general building construction

5.17 Design Life

The design life of all structures and buildings shall be 60 years.

5.18 Joints

Movement joints such as expansion joints, complete contraction joints, partial contraction joints and sliding joints shall be designed to suit the structure. However, contraction joints shall be provided at specified locations spaced not more than 7.5 m in both right angle directions for walls and rafts. Expansion joints of suitable gap at suitable intervals not more than 30 m shall be provided in walls, floors and roof slabs of water retaining structures. Construction joints shall be provided at right angles to the general direction of the member. The locations of construction joints shall be decided on convenience of construction. To avoid segregation of concrete in walls, horizontal construction joints are normally to be provided at every 2 m height. PVC waterstops of 150 mm width shall be used for walls and 230 mm width for base slabs.

5.19 Design Loadings

All buildings and structures shall be designed to resist the worst combination of the following loads/stresses under test and working conditions; these include dead load, live load, wind load, seismic load, and stresses due to temperature changes, shrinkage and creep in materials, dynamic loads:

5.19.1 Dead Load

This shall comprise all permanent construction including walls, floors, roofs, partitions, stairways, fixed service equipment and other items of machinery. In estimating the loads of process equipment all fixtures and attached piping shall be included, but excluding contents, shall be considered. The following minimum loads shall be considered in design of structures:

(i)	Weight of water	9.81 kN/m^3
(ii)	Weight of soil (irrespective of strata available at site and type of soil used for filling etc). However, for checking stability against uplift, actual weight of soil as determined by field test shall be considered	20.00 kN/m^3
(iii)	Weight of plain concrete	24.00 kN/m^3
(iv)	Weight of reinforced concrete	25.00 kN/m^3
(v)	Weight of brickwork (exclusive of plaster)	22.00 N/m^2 per mm thickness of brickwork
(vi)	Weight of plaster to masonry surface	18.00 N/m^2 per mm thickness
(vii)	Weight of granolithic terrazo finish or rendering screed, etc.	24.00 N/m^2 per mm thickness
(viii)	Weight of sand (filter media)	26 kN/m^3
(ix)	Weight of alum blocks	24.20 kN/m^3
(x)	Weight of MS chequered plates	78.5 N/m2 per mm thickness of plates

5.19.2 Live Load

Live Load (LL) shall include the superimposed loads due to the use/occupancy of the structure/building not including dead, wind or earthquake load. Live loads shall be in general as per IS:875 Part (II). However, the following minimum loads shall be considered in the design of structures:

(i)	Live load on roofs	1.50 kN/m^2
(ii)	Live load on floors supporting equipment such as pumps, blowers, compressors, valves etc.	10.00 kN/m^2
(iii)	Live load on all other floors walkways, stairways and platforms	5.00 kN/m^2

In the absence of any suitable provisions for live loads in IS Codes or as given above for any particular type of floor or structure, assumptions made must receive the approval of the Engineer prior to starting the design work. Apart from the specified live loads or any other load due to material stored, any other equipment load or possible overloading during maintenance or erection/construction shall be considered and shall be partial or full whichever causes the most critical condition.

5.19.3 **Wind Load**

Wind loads shall be as per IS:875 Part (III).

5.19.4 **Earthquake Load**

This shall be computed as per IS:1893. An importance factor appropriate to the type of structure shall be considered for design of all the structures. Chennai comes under Earthquake zone III.

5.19.5 **Dynamic Load**

Dynamic loads due to working of plant items such as pumps, blowers, compressors, switch gears, travelling cranes, etc. shall be considered in the design of structures.

5.20 Design Conditions for Liquid Retaining Structures

Water level is assumed at the ground level for design of all the structures. All underground or partly underground liquid containing structures shall be designed for the following conditions:

(i) Liquid depth up to full height of wall including free board: no relief due to soil pressure from outside to be considered

(ii) structure empty (i.e., empty of liquid, any material, etc.): full earth pressure and surcharge pressure wherever applicable, to be considered

(iii) partition wall between dry sump and wet sump: to be designed for full liquid depth up to full height of wall

(iv) partition wall between two compartments: to be designed as one compartment empty and other full

(v) structures shall be designed for uplift in empty conditions with the water table as indicated in geotechnical report

(vi) walls shall be designed under operating conditions to resist earthquake forces from earth pressure mobilisation and dynamic water loads

(vii) Underground or partially underground structures shall also be checked against stresses developed due to any combination of full and empty compartments with appropriate ground/uplift pressures from below to base slab. A minimum factor of 1.2 shall be ensured against uplift or floatation.

(viii) All the liquid retaining structures shall be designed for maximum design crack width of 0.1 mm for direct tension and flexure.

5.21 Foundations

(i) The minimum depth of foundations for all structures, equipment, buildings and frame foundations and load bearing walls shall be as per IS:1904 but in any case this shall not be less than 1.0 meter in the original soil.

(ii) Maximum safe bearing capacity of soil strata shall be taken as indicated in geotechnical reports.

(iii) Care shall be taken to avoid the foundations of adjacent buildings or structure foundations, either existing or not within the scope of this Contract. Suitable adjustments in depth, location and sizes may have to be made depending on site conditions. No extra claims for such adjustments shall be accepted by the Engineer.

(iv) Special attention is drawn to the danger of the uplift being caused by the ground water table. All underground structural slabs shall be designed for uplift forces due to ground water pressure.

5.22 Design Requirements

The following are the design requirements for all reinforced or plain concrete structures:

(i) All blinding and leveling concrete shall be a minimum 150 mm thick in concrete grade M15.

(ii) For all water retaining reinforced concrete structures, concrete shall be of a minimum M35 grade and for all other reinforced concrete structures, reinforced concrete shall be of a minimum M30 grade. Maximum aggregate size shall be 20 mm for all the reinforced concrete works.

(iii) The concrete for reinforced concrete structures shall have a minimum cement content of 360 kg/m3 with a maximum 20 mm size aggregate. Reinforced concrete shall have minimum slump of 100mm with maximum water cement ratio of 0.45.

(iv) The minimum clear cover to all reinforcement including stirrups and links shall be 50 mm for all water retaining structures. As a design consideration to control the crack, though general requirement shall be as per IS:3370 but all the water retaining structures including roof slab shall be designed on permissible crack width of 0.1 mm (as per BS 8007).

(v) The amount of reinforcement in each of the two directions at right angles within each surface zone should not be less than 0.35% of the surface zone cross section (as per Clause 2.6.2.3 of BS 8007-1987). For slabs, minimum of 10 mm dia bars shall be used to avoid any deformation of lesser diameter bars under loads prior to construction.

(vi) The minimum cover to the main reinforcing bars for different members for non–water retaining structures shall be as follows unless stated otherwise:

Slab (Floor, Roof, Canopy, and Staircase)	:	30 mm
Beams (Sides, Bottom & Top)	:	40 mm
Columns	:	50 mm
Pedestals (in contact with earth)	:	50 mm
Basement wall, retaining walls		
a) Face in contact with earth	:	40 mm
b) Interior face	:	30 mm

Foundations : 50 mm

(vii) For reinforced concrete structures, reinforcement shall be HYSD Steel of grade Fe 415.

(viii) All buildings shall have a minimum 1 meter wide, 100 mm thick plinth protection paving in M20 grade concrete or stone slabs/tiles. All plinth protection shall be supported on well compacted strata.

(ix) All pipes and ducts laid below the structural plinth and road works shall be surrounded with concrete of minimum grade M15.

(x) Detailing of the reinforcement and sizing of structural members shall be done as per latest IS:-13920.

(xi) Any structure or pipeline crossing below roads shall be designed for Class 'A' of IRC loading.

(xii) Sliding layer or slip layer shall be provided between sub base and structural slab (Raft). Polythene sheets of 1000 gauge shall be provided as sliding layer as per IS specification.

(xiii) Water tightness testing of water retaining structures shall be performed in accordance with IS:3370 (Part I). It is described in Clause 5.34 under this Part-5. The depth of water for testing shall be up to the soffit of the covering slab.

The following minimum thicknesses shall be used for different reinforced concrete members, irrespective of design thicknesses:

(i)	Walls for liquid retaining structures	300 mm
(ii)	Roof slabs for liquid retaining structures (other than flat slabs)	240 mm
(iii)	Bottom slabs/Raft for liquid retaining structures	300 mm
(iv)	Floor slabs including roof slabs, walkways, canopy slabs	125 mm
(v)	Walls of cables/pipe trenches, underground pits, etc.	150 mm
(vi)	Column footings	450 mm
(vii)	Parapets, chajja	125 mm
(viii)	Precast trench cover	75 mm

(xiv) Design of all reinforced concrete structures shall be as per IS:456, of pre-stressed concrete structures as per IS:1343. The structural safety of all foundations on soil shall, in general be based on IS:1904.

(xv) For calculation purpose "Limit state Design" methods according to IS:456-2000 shall generally be adopted, except for water retaining structures where IS:3370 (Part I-IV) shall be referred and other special cases requiring design by working stress method.

(xvi) All grouting below machine/equipment bases, and pockets shall be non-shrinking grout of adequate thickness and minimum grade of M35 with 6mm and down aggregates. Grouting below structural column bases shall be minimum grade of M30 with 6mm and down aggregates.

(xvii) PCC grade M15 – Apron, plinth protection, screed concrete, foundation below masonry walls, encasing of underground pipes & conduits, ground floor at plinth level, toilet, rest room, etc.

(xviii) All foundations and concrete structures shall be designed to resist full operating dead and live loads, with appropriate combination of wind and seismic forces and with due allowance for impact, inertia loading, vibration, unbalanced dynamic loads, etc. as secondary effect of live loads, erection loads, temperature variation etc. While designing structures and foundations either the effect of seismic forces or wind loads, whichever produces the worst effect, shall be considered along with usual load conditions. Apart from the installation and operating loads indicated by the equipment manufacturers, the design of buildings and structures shall be based on dead and imposed loads calculated according to IS:875. All structures shall be designed for seismic load as per IS1893 2002/latest in the category one above as stated in the specified code.

(xix) Concentrated and uniformly distributed live load on floors and platforms shall be considered depending upon the usage and in accordance with maximum expected process requirements, to be indicated by the equipment manufactures. When the loads are movable, they shall be so placed as to get worst effect in moment & shear, axial load etc. for which the elements shall be designed. The effect of concentrated load shall not be reduced. Due allowance shall be made, wherever necessary, for installation and operation of any equipment as per equipment manufacturer's data and recommendations. The design shall be based on the maximum loading due to uniform live load and/or equipment loading including impact, vibration, unbalanced operating forces, etc.

(xx) Foundations for structures and equipment shall be proportioned to resist the worst combination of loading and shall generally be designed as per the provision of IS:1904 for open foundations on soil and IS: 2911 for foundations on piles.

5.23 Concrete and Allied Works

5.23.1 **Materials in General**

The term "materials" shall mean all materials, goods and articles of every kind whether raw, processed or manufactured and equipment and plant of every kind to be supplied by the Contractor for incorporation in the Works. Except as may be otherwise specified for particular parts of the Works, the provision of clauses in "Materials and Workmanship" shall apply to materials and workmanship for any part of the Works. All materials shall be new and of the kinds and qualities described in the Contract and shall be at least equal to approved samples.

As soon as practicable after receiving the order to commence the Works, the Contractor shall inform to the Engineer of the names of the suppliers from whom he proposes to obtain any materials but he shall not place any order without the approval of the Engineer which may be withheld until samples have been submitted and satisfactorily tested. The Contractor shall thereafter keep the Engineer informed of orders for and delivery dates of all materials.

Materials shall be transported, handled and stored in such a manner as to prevent deterioration, damage or contamination failing which such damaged materials will be rejected and shall not be used on any part of the Works under this contract.

The quality of materials and method and control of manufacture and transportation of all concrete work irrespective of mix, whether reinforced or otherwise, shall conform to the applicable portions of this specification. The Employer's representative shall have the right to inspect the source/s of material/s, the layout and operation of procurement and storage of materials, the concrete batching and mixing equipment and the quality control system. Such an inspection shall be arranged and Employer's representative approval obtained, prior to starting of concrete work.

5.23.2 **Materials for Standard Concrete**

The ingredients to be used in the manufacture of concrete shall consist solely of Portland cement, clean sand, natural coarse aggregate, clean water and admixtures, if specifically called for on drawings or specifications, or to the approval of the Employer's Representative if conditions at site warrant its use.

5.23.2.1 *Cement*

Unless otherwise specified in the Specification or called for by the Employer's Representative, cement shall be ordinary Portland cement (OPC-43 grade) Bags conforming to IS:269 unless specifically defined. The use of bulk cement will be permitted only with the approval of the Employer's Representative. Changing of brands or type of cement within the same structure should be avoided as far as possible.

However, cement for all works submerged under sea water shall be Portland Slag cemet43 grade in 50 kg. Bags conforming to IS:269 unless specifically defined. The use of bulk cement will be permitted only with the approval of the Employer's Representative. Changing of brands or type of cement within the same structure should be avoided as far as possible. Sample shall be tested at approved Laboratory at Contractor's cost from each lot of cement delivered at site.

The Contractor will have to make his own arrangements for the supply and storage of an adequate quantity of cement. Employer will not supply cement. It will be the responsibility of the Contractor to ensure adequate and proper storage and complete protection from dampness, contamination and minimize caking and false set. Cement bags shall be stored in a dry enclosed shed (storage under tarpaulins will not be permitted), well away from the outer walls, and insulated from the floor to avoid contact with moisture from the ground and so arranged as to provide ready access. Damaged or reclaimed or partly set cement will not be permitted to be used and shall be removed from the site. The storage arrangement shall be such there is no dead storage. Not more than 12 bags shall be stacked in any tier. The Employer's Representative shall approve the storage arrangement. Consignments cement shall be stored as received and shall be consumed in the order of their delivery.

Cement held in storage for a period of ninety (90) days or longer shall be tested. Should at any time the Employer’s Representative have reasons to consider that any cement is defective, then irrespective of it origin, date of manufacture and/or manufacture's test certificate, such cement shall be tested immediately at the Contractor's cost at the approved laboratory and until the results of such tests are found satisfactory, it shall not be used in any work. The Contractor shall not be entitled to any claim of any nature on this account.

5.23.2.2 *Aggregates*

i) General

'Aggregate" in general designates both fine and coarse inert materials is used in the manufacture of concrete.

"Fine Aggregate" is aggregate most of which passes through 4.75 mm IS sieve.

“Coarse Aggregate" is aggregate most of which is retained on 4.75 mm IS sieve.

All fine and coarse aggregates proposed for use in the Works shall be subject to the Employer’s Representative's approval and after specific materials have been accepted, the source of supply of such materials shall not be changed without prior approval of the Employer’s Representative.

Aggregates shall, except as noted above, consist of natural sands, crushed stone and gravel from a source known to produce satisfactory aggregate for concrete and shall be chemically inert, strong, hard, durable against weathering, of limited porosity and free from deleterious materials that may cause corrosion of the reinforcement or may impair the strength shall such as to produce a dense concrete of specified strength and consistency that will work readily into position without segregation and shall be based on the "mix design" and preliminary tests on concrete specified later.

ii) Sampling and Testing

Samples of the aggregates for mix design and determination of suitability shall be taken under the supervision of Employer’s Representative and delivered to the laboratory, well in advance of the scheduled placing of concrete. Records of tests which have been made on proposed aggregates and on concrete made from this source of aggregates shall be furnished to Employer’s Representative in advance of the work for use in determining aggregate suitability. The costs of all such tests, sampling, etc., shall be borne me by Contractor.

iii) Storage of Aggregates

All coarse and fine aggregates shall be stacked separately in stock piles in the material yard near the work site in bins properly constructed to avoid inter mixing of different aggregates. Contamination with foreign material and earth during storage and while heaping the materials shall be avoided. The aggregate must be of specified quality not only at the time of receiving at site but more so at the time of loading into mixer. Rakers shall be used for lifting the coarse aggregates from bins or stockpiles. Coarse aggregate shall be piled in layers not exceeding 1.20 meters in height to prevent coning or segregation. Each layers shall cover the entire area of the stock pile before succeeding layers are started. Aggregates that have become segregated shall be rejected. Rejected material after remixing may be accepted, if subsequent tests demonstrate conformance with required gradation.

iv) Specific Gravity

Aggregates having a specific gravity below 2.6 (saturated surface dry basis) shall not be used without special permission of the Employer's Representative.

5.23.3 **Fine Aggregate**

Fine aggregate shall consist of natural or crushed sand conforming to I.S. 383. The sand shall be clean, sharp, hard strong and durable and shall be free from dust, vegetable substances, adherent coating, clay, alkali, organic matter, mica, salt, or other deleterious substances, which can be injurious to the setting qualities/strength/durability of concrete.

a) Machine-made Sand

Machine-made sand will be acceptable, provided the constituent rock gravel composition shall be sound, hard, dense, non-organic, uncoated and durable against weathering.

b) Screening and Washing

Sand shall be prepared for use by such screening or washing, or both, as necessary, to remove all objectionable foreign matter while separating the sand grains to the required size tractions.

c) Foreign Material Limitations

The percentage of deleterious substance in sand delivered to, the mixer shall not exceed the following:

Table 5.1

		Percent by weight	
		Uncrushed	Crushed
i)	Material finer than 75 micron I.S sieve	3.00	15.00
ii)	Shale	1.00	—
iii)	Coal and lignite	1.00	1.00
iv)	Clay lumps	1.00	1.00
v)	Total of all above substances including items (i) to (iv) for uncrushed sand and items (iii) and (iv) for Crushed sand	5.00	2.00

d) Gradation

Unless otherwise directed or approved by the Employer's Representative, the grading of sand shall be within the limits indicated hereunder.

Table 5.2

	Percentage Passing for			
I.S. Sieve Designation	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV

10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
600 micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

Where the grading falls outside the limits of any particular grading zone of sieves, other than 600 micron I.S. sieve, by total amount not exceeding 5 percent, it shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing the 600 micron IS. sieve or to percentage passing any other sieve size on the coarser limit of Grading Zone I or the finer limit of Grading Zone IV. Fine aggregates conforming to Grading Zone IV shall be used unless mix designs and preliminary tests shall show its suitability for producing concrete of specified strength and workability.

e) Fineness Modulus

The sand shall have a fineness modulus of not less than 2.2 or more than 3.2. The fineness modulus is determined by adding the cumulative percentages retained on the following I.S. sieve sizes (4.75mm, 2.36mm, 1.18mm, 600micron, 300micron and 150micron) and dividing the sum by 100.

5.23.4 **Coarse Aggregate**

Coarse aggregate for concrete, except as noted above, shall conform to IS: 383. This shall consist of natural or crushed stone and gravel, and shall be clean, and free from elongated, flaky or laminated pieces, adhering coatings, clay lumps, coal residue, clinkers, slag, alkali, mica, organic matter or other deleterious matter.

a) Screening and Washing

Natural gravel and crushed rock shall be screened and/or washed for the removal of dirt or dust coating, if so directed by the Employer's Representative.

b) Grading

Coarse aggregate shall be either in single size or graded, in both cases the grading shall be within the following limits:

I.S. Sieve Designa-tion	**Table-5.3**								
	Percentage passing for single sized aggregate of nominal size					Percentage passing for Graded aggregate of nominal size			
	40 mm	20mm	16mm	12.5mm	10mm	40mm	20mm	16mm	12.5mm
63 mm	100	-	-	-	-	100	-	-	-
40 mm	85-100	100	-	-	-	95-100	100	-	-
20 mm	0-20	85-100	100	-	-	30-70	95-100	100	-

16 mm	-	-	85-100	100	-	-	-	90-100	-
12.5 mm	-	-	-	85-100	100	-	-	-	90-100
10 mm	0-5	0-20	0-30	0-45	85-100	10-35	25-55	30-70	40-85
4.75 mm	-	0-5	0-5	0-10	0-20	0-5	0-10	0-10	0-10
2.36 mm	-	-	-	-	0-5	-	-	-	-

The pieces shall be angular in shape and shall have granular or crystalline surfaces. Friable, flaky and laminated pieces, mica and shale, if present, shall be only in such quantities that will not, in the opinion of the Employer's Representative, affect adversely the strength and/or durability of concrete. The maximum size of coarse shall be the maximum size specified above, but in no case greater than 1/4 the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form. Plums above 160 mm and upto any reasonable size can be used in plain mass concrete work of large dimensions upto a maximum limit of 20% by volume of concrete when specifically approved by Employer's Representative. For heavily reinforced concrete members, the nominal maximum size of the aggregate shall be 5 mm less than the minimum clear distance between the reinforcing main bars or 5 mm less than the minimum cover to the reinforcement whichever is smaller. The amount of fine particles occurring in the free state or as loose adherent shall not exceed 1% when determined by laboratory sedimentation tests as per I.S, 2386. After 24 hours immersion in water, a previously dried sample shall not have gained more than 10% of its oven dry weight in air, as determined by I.S. 2386.

c) Foreign Material Limitations

The percentage of deleterious substances in the aggregate delivered to the mixer shall not exceed the following:

Table -5.4

S.N.	**Foreign Material**	**Percent by weight**	
		Uncrushed	**Crushed**
i)	Material finer than 75 micron I.S Sieve	3.00	3.00
ii)	Coal and lignite	1.00	1.00
iii)	Clay lumps	1.00	1.00
iv)	Soft fragments	3.00	—
v)	Total of all the above substances	5.00	5.00

5.23.5 **Water**

Water used for both mixing and curing, shall be free from injurious amounts of deleterious materials. Potable water is generally satisfactory for mixing and curing concrete.

In case of doubt, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time test specified in I.S. 456. The sample of water for testing shall be typical of the water proposed to be used for concreting, due account being paid to seasonal variation. The sample shall not receive any treatment before testing other than that envisaged in the regular supply of water proposed for use in concrete. The sample shall be stored in a clean container previously rinsed out with similar water.

Average 28-day compressive strength of at least three 15 cm concrete cubes prepared with water proposed to be used shall not less than 90% of the average strength of three similar concrete cubes prepared with distilled water. The cubes shall be prepared, cured and tested in accordance with the requirements of I.S. 516.

The initial setting time of test block made with the appropriate test cement and the water proposed to be used shall not be less than 30 minutes and shall not differ by more than ±30 minutes from the initial setting time of control test block prepared with the appropriate test cement and distilled water. The test blocks shall be prepared and tested in accordance with the requirements of I.S. 4031.

Where water can be shown to contain an excess of acid, alkali, sugar or salt, Employer's Representative may refuse to permit its use. As a guide, the following concentrations represent the maximum permissible values:

(a) To neutralize 200 ml, sample of water, using Phenolphthalein as indicator, it should not require more than 2 ml. of 0.1 Normal NaOH. The details of test shall be as given in I.S: 3025.

(b) To neutralize 200-ml. sample of water, using methyl orange, as an indicator should not require more than 10 ml. of 0.1 Normal HCL. The details of test shall be as given in I.S: 3025.

(c) Percentage of solids, when tested in accordance with the method indicated below, shall not exceed the following:

Table -5.5

Solids	Percent	Method of Test
		(Ref. to Cause No. In IS :3025)
Organic	0.02	10 and 11 (organic solids = total solids minus ignited residue)
Inorganic	0.30	11 (ignited residue)
Sulphates (as SO4)	0.05	20
Alkali Chloride (As Cl)	0.20	24
Suspended matter	0.20	12

5.24 Steel Members Encased in Concrete

Structural steel columns, beams, girders and bracings to be encased in concrete shall be unpainted. The encasing shall be done in concrete with 10 mm maximum size aggregate and works cube strength not less than 15 N/mm2 at 28 days unless otherwise specified. The steel member shall be wrapped with galvanised wire mesh of adequate size.

All stell members in the floor level in tanks contact with sea water shall be embeed in concrete for min. 450 mm above the fished floor level.

The galvanised wire mesh shall be at 20 mm from the edge or surface of the steel member and shall be held in position securely. The steel, member will have a minimum cover of 50 mm unless otherwise indicated on the drawings. Where the clear cover to steel is more than 75mm, mild steel bar and concrete with 20 mm coarse aggregate can be used.

5.24.1 **Controlled Concrete**

All concrete in the works shall be "controlled concrete" as defined in IS 456, except for M7.5 and M10 for which nominal mix concrete shall be used. Whether reinforced or otherwise, all concrete works to be carried out under this specification shall be divide into the following classification:

<table>
<tr><td colspan="7">TABLE - 5.6
Minimum compressive strength of 15 cm. Cubes at 7 and 28 days after mixing conducted in accordance with I.S. 516</td></tr>
<tr><td>Class</td><td colspan="2">Preliminary test N/mm2</td><td colspan="2">Works test N/mm2</td><td>Max. size of aggregate</td><td>Locations for use</td></tr>
<tr><td></td><td>At 7 days</td><td>At 28 days</td><td>At 7 days</td><td>At 28 days</td><td></td><td></td></tr>
<tr><td>M40</td><td>33.5</td><td>50.0</td><td>27.0</td><td>40.0</td><td>20</td><td rowspan="6">As indicated in the specifications or as required.</td></tr>
<tr><td>M35</td><td>30.0</td><td>44.0</td><td>23.5</td><td>35.0</td><td>20</td></tr>
<tr><td>M30</td><td>25.0</td><td>38.0</td><td>20.0</td><td>30.0</td><td>40 or 20</td></tr>
<tr><td>M25</td><td>22.0</td><td>32.0</td><td>17.0</td><td>25.0</td><td>40 or 20</td></tr>
<tr><td>M20</td><td>17.5</td><td>26.0</td><td>13.5</td><td>20.0</td><td>40 or 20</td></tr>
<tr><td>M15</td><td>13.5</td><td>20.0</td><td>10.0</td><td>15.0</td><td>40 or 20</td></tr>
</table>

Notes: It shall be very clearly understood that whenever the concrete such M 20, etc. is specified it shall be Contractor's responsibility to ensure that minimum crushing strength stipulated for the respective grade of concrete is obtained at works.

Minimum cement content in the concrete used for liquid/ water retaining structure shall be 360 kg/m3 for 20 mm downgraded aggregate and 325 kg/m3 for 40 mm downgraded aggregate.

5.24.2 **Mix Design**

5.24.2.1 *General*

This is to investigate the grading of aggregates, water cement ratio, workability and the quantity of cement required to give preliminary and works cubes of the minimum strengths specified. The proportions of the mix shall be determined by weight. Adjustment of aggregate proportions due to moisture present in the aggregate shall be made.

Determination of mix proportions shall be carried out according to "Recommended Guidelines for Concrete Mix Design' conforming to IS: 10262.

Whenever there is change either in required strength of concrete, or water-cement ratio or workability or the source of aggregates and/or cement, preliminary tests shall be repeated to determine the revised proportions of the mix to suit the altered conditions. While designing mix proportions, over-wet mixes shall always be avoided. While fixing the value for water/cement ratio for preliminary mixes, assistance maybe derived from IS: 456.

The Contractor shall give the Engineer seven days' notice in writing, of the date on which, any of the materials will be ready for testing or inspection at the supplier's premises or at a laboratory approved by the Engineer. The Employer's representative shall attend the test at the appointed place within seven days of the said date on which the materials are expected to be ready for testing or inspection according to the Contractor, failing which the test may proceed in his absence unless instructed by the Engineer to carry out such a test on a mutually agreed date in his or his representative's presence. The Contractor shall in any case submit to the Engineer, within seven days of every test, such number of certified copies (not exceeding six) of the test results as the Engineer may require. Approval by the Engineer, as to the placing of orders for materials or as to samples or tests, shall not prejudice any of the Engineer's powers under the Contract. The provisions of this clause shall also apply to materials supplied under any nominated sub-contract.

5.24.2.2 *Preliminary Tests*

Test specimens shall be prepared with at least two different water/cement ratios for each class of concrete, consistent with workability required for the nature of the work.

The materials and proportions used in making preliminary tests shall be similar in all respects to those to be actually employed in the works as the object of these tests is to determine the proportions of cement, aggregates and water necessary to produce concrete of required consistency and to give the specified strength. It will be Contractor's sole responsibility to carry out these tests and he shall therefore furnish to Employer's Representative a statement of proportions proposed to be used for the various concrete mixes. For preliminary tests, the following procedure shall be followed:

Materials shall be brought to the room temperature and all materials shall be in a dry condition. The quantities of water, cement and aggregates for each batch shall be determined by weight to an accuracy of 1 part in 1000 parts.

(i) Mixing Concrete

It shall be done by hand or in a small batch mixer as per I.S. 516 in such a manner as to avoid loss of water. The cement and fine aggregate shall first be mixed dry until the mixture is uniform in colour. The coarse aggregate shall then be added, mixed and water added and the whole batch mixed thoroughly for a period of not less than two minute until the resulting concrete is uniform in appearance. Each batch of, concrete shall be of such a size as to leave about 10% excess concrete, after moulding the desired number of test specimens.

(ii) Consistency

The consistency of each batch of concrete shall be measured immediately after mixing, by the slump test in accordance with I.S. 1199. If in the slump test, care is taken to ensure that no water or other material is lost, the material used for the slump test may be remixed with the remainder of the concrete for making the specimen test cubes. The period of re-mixing shall be as short as possible yet sufficient to produce a homogeneous mass.

(iii) Size of Test Cubes

Compression tests of concrete cubes shall be made as per I.S.516 on 15 cm. cubes. Each mould shall be provided with a metal base plate having a plain surface so as to support the mould during filling without leakage.

The base plate shall be preferably attached to the mould when assembled shall be positively and rigidly held together. Before placing concrete, the mould and base plate shall be cleaned and oiled. The dimensions and internal faces of the mould shall be accurate within the following limits:

Height and distance between the opposite faces of the mould shall be of specified size +0.2 mm. The angle between the adjacent internal faces and between internal faces and top and bottom faces of mould shall be 90 +_ 0.5°. The interior faces of the mould shall be plain surface with a permissible variation of 0.03 mm.

(iv) Compacting

Concrete test cubes shall be moulded by placing fresh concrete in the mould and compacted as specified in I.S. 516.

(v) Curing

Curing shall be as specified in I.S.516. The cubes shall be kept in moist air of at least 90% relative humidity at a temperature of 27° ±_2° C for 24 hours ±1/2 hour from the time of adding water to the dry ingredients. Thereafter they shall be removed from the moulds and kept immersed in clean, fresh water and kept at 27° ± 2° C temperature "until required for test. Curing water shall be renewed every seven days. A record of maximum temperatures at the place of-storage of the cubes shall be maintained during the period they remain in storage.

(vi) Testing of Specimens

The strength shall be determined based on not less that five cube test specimens for each age and each water cement ratio. All these laboratory test results shall be tabulated and furnished to the Employer's Representative. The test results shall be accepted by the Employer's Representative if the average compressive strength of the specimens tested is not less than the compressive strength specified for the age at which specimens are tested subject to the condition that only one out of the five consecutive tests may give a value less than the specified strength for that age. The Employer's Representative may direct the Contractor to repeat the tests if the results are not satisfactory and also make such changes as he considers necessary to meet the requirement specified. All there preliminary tests shall be conducted by the Contractor at his own cost in approved laboratory.

5.24.3 Proportioning, Consistency, Batching and Mixing of Concrete

5.24.3.1 *Proportioning*

(i) Aggregate

The proportions which shall be decided by conducting preliminary tests shall be by weight. These proportions of cement, fine and coarse aggregates shall be maintained during subsequent concrete batching by means of weigh batchers conforming to I.S. 2722 capable of controlling the weights within one percent of the desired value. Except where it can be shown to the satisfaction of the Employer's Representative that supply of properly graded aggregate of uniform quality can be maintained over the period of work, the grading of aggregate shall be controlled by obtaining the coarse aggregate in different sizes and blending them in the right proportions.

The different sizes shall be stocked in separate stock piles. The grading of coarse and fine aggregate shall be checked as frequently as possible, as determined by the Employer's Representative, to ensure maintaining of grading in accordance with the samples used in preliminary mix design. The material shall be stock piles well in advance of use.

(ii) Cement

Cement shall be measured by weight.

(iii) Water

Only such quantity of water shall be added to the cement and aggregates in the concrete mix as to ensure dense concrete, specified surface finish satisfactory workability, consistent with the strength stipulated for each class of concrete. The water added to the mix shall be such as not to cause aggregation of materials or the collection of excessive free water on the surface of the concrete.

(iv) Definition of Water/ Cement Ratio

The water cement (W/C) ratio is defined as the weight of water in the mix (including the surface moisture of the aggregates) divided by the weight of cement in the mix.

(v) Water/ Cement Ratio

The actual water cement ratio to be adopted shall be determined in each instance by the Contractor and approved by the Employer's Representative

(vi) Proportioning by Water/ Cement Ratio

The W/C ratio specified for use by the Employer's Representativeshall be maintained. The Contractor shall determine the water content of the aggregates as frequently as directed by the Employer's Representative as the work progresses and as specified in I.S. 2386 (Part ID) and the amount of mixing water added at the mixer shall be adjusted as directed by the Employer's Representative so as to maintain the specified W/C ratio. To allow for the variation in weight of aggregates due to variation in their moisture content, suitable adjustments in the weights of aggregates shall also be made.

5.24.3.2 *Consistency and Slump*

Concrete shall be of consistency and workability suitable for the conditions of the job. After the amount of water required is determined, the consistency of the mix shall be maintained throughout the progress of the corresponding parts of the work and approved tests e.g. slump tests, compacting factor tests, in accordance with I.S.1199, shall be conducted from time to time to ensure the maintenance of such consistency.

The following tabulation gives a range of slumps which shall generally be used for various types of construction unless otherwise instructed by the Employer's Representative:

TABLE 5.7
Slumps for Various Types of Construction

Works Details	Slump in millimeters	
	Maximum	Minimum
Reinforced foundation walls and footings	75	25
Plain footings and substructure walls	75	25
Slabs, Beams and reinforced walls	100	25
Pumps & Miscellaneous Equipment foundations	75	25
Building Columns	100	25
Pavements	50	25
Heavy Mass Construction	50	25

5.24.3.3 *Batching and Mixing of Concrete*

The materials and proportions of concrete materials as established by the preliminary tests for the mix designs shall be rigidly followed for all concrete on the Works and shall not be changed except when specifically permitted by the Employer's Representative.

Concrete shall be produced only by weigh batching the ingredients. The mixer and weigh batchers shall be maintained in clean, serviceable condition. The accuracy of weigh batchers shall be periodically checked. They shall be set up level on a firm base and the hopper is empty. Fine and coarse aggregates shall be weighed separately. Volume batching will not be permitted. However, the Employer's Representative may permit volume batching by subsequent conversion of the weights of the aggregate into their equivalent volumes knowing their bulk densities, only in the case of small and less important pours involving weigh batching are not likely to be taken up. Concrete shall be of strength stipulated in the respective items. All concrete shall be mixed in mechanically operated batch mixers complying with I.S. 1791 and of the approved make with suitable provision for correctly controlling the water delivered to the drum. The quantity of water actually entering the drum shall be checked with the reading of the gauge or valve setting, when starting a job. The test should be made while the mixer is running. The volume of the mixed material shall not exceed the manufacturer's rated mixer capacity. The batch shall be charged into the mixer so that some water will enter the drum in advance of cement and aggregates. All water shall be in the drum by the end of the first 15 seconds of the specified mixing time.

Each batch shall be mixed until the concrete is uniform in colour, for a minimum period of two minutes after all the materials and water are in the drum. The entire contents of the drum shall be discharged in one operation before the raw materials for the succeeding batches are fed into the drum. Each time the work stops, the mixer shall be cleaned out and when next commencing the mixing, the first batch shall have 10% additional cement to allow for sticking in the drum.

5.25 Mix Design Reinforced Concrete

All water retaining structures shall be designed as per IS3370 part I to IV.

The works under this head covers all activities including raw materials, transportation to site, Reinforced Cement Concrete grades M15, M20, M30, M35, M40 shall be mix design as specified in General Specifications. In case WPC is required to be added (if specified), same shall conform with general specifications in all respects. Admixtures, as specified in General Specifications, shall be added, if directed by Employer's Representative depending on grade of concrete and construction requirements without any extra cost implication. Minimum M 30 grade for buildings and M-35 for Water Retaining Structures shall be used, no grade below the said is permissible.

Contractor shall comply with all testing requirements as specified in General Specifications for raw materials and concrete (for all grades of concrete).

5.25.1 **Admixtures**

5.25.1.1 *General*

Admixtures may be used in concrete where required, only with the approval of the Employer's Representative based upon evidence that, with the passage of time, neither the compressive strength not its durability reduced.

Calcium chloride shall not be used for accelerating set of the cement for concrete containing reinforcement, or embedded steel parts. When calcium chloride is permitted to be used, such as in mass concrete works, it shall be dissolved in water and added to the mixing water in an amount not to exceed 1 1/2 % of the weight of the cement in each batch of concrete. When admixtures are used, the designed concrete mix shall be corrected accordingly. Admixtures shall be used as per manufacturer's instructions and in the manner and with the control specified by the Employer's Representative.

5.25.1.2 *Air Entraining Agents*

Neutralized vinsol resin or any other approved air entraining agent may be used to produce the specified amount of air in the concrete mix and these agents shall conform to the requirements of ASTM standard 6-20. Air entraining admixtures for concrete. The recommended total air content of the concrete is 4% ± 1%. The method of measuring air content shall be as per IS: 1199.

5.25.1.3 *Water Reducing Admixtures*

Water reducing lignosulfonate admixture may be added in quantities approved by the Employer's Representative. The admixtures shall be added in the form of a solution.

5.25.1.4 *Retarding Admixtures*

Retarding agents may be added to the concrete mix in quantities approved by the Employer's Representative.

5.25.1.5 *Water-Proofing Compound*

i) As directed by the Employer's Representative, the Contractor shall use approved waterproofing compound made by manufacturers as per list of makes in Section-X, Volume-2, Employers requirement. In the reinforced concrete works. The quantity to be used shall be two percent by weight of cement or shall be in accordance with the manufacturer's instructions subject however to the approval of the Employer's Representative. The compound shall not contain calcium chloride and shall conform to IS: 2645.

ii) Mixing water proofing compound with cement. The compound should be mixed thoroughly with the cement by hand before the cement is mixed with aggregate. Thorough mixing is essential. The two materials should be heaped on a mixing board thoroughly turned over several times with a shovel and finally passed through a fine sieve. If labour is unsatisfactory the sieving should be done twice to ensure maximum dispersal of the compound throughout the cement.

iii) Mixing the concrete - The mixture of water proofing compound and cement should then be added to the aggregate, the dry materials turned over twice and the correct amount of water then added through a rose spray, A further thorough mixing by spade should immediately follow. Only the minimum quantity of water necessary to give workability should be used such that it will make the concrete just sufficiently plastic for purposes of placing and thorough consolidation without affecting its strength.

5.25.1.6 *Corrosion Inhibitors*

Corrosion Inhibitors shall be added to concreting for water retaining structures in contact with sea water as well for use of concrete to embed the structural steel.

5.25.2 **Concrete in Alkali Soils and Alkaline Water**

Where concrete is vulnerable to attack from alkali salts or alkaline water, special cements containing low amount of tricalcium aluminate shall be used, if so specified or directed. Such concrete shall have a minimum 28 days compressive strength of 25 N/mm2 and shall contain not less than 3.7 KN of cement per cubic metre of concrete in place. If specified, additional protection shall be obtained by the use of chemically resistant stone facing or a layer of Plaster of Paris covered with suitable fabric, such as jute thoroughly impregnated with tar.

5.25.3 **Preparation Prior to Concrete Placement - Final Inspection and Approval**

Before the concrete is actually placed in position, the insides of the formwork shall be inspected to see that they have been cleaned and oiled. Temporary openings shall be provided to facilitate inspection, especially of bottoms of columns and wall forms, to permit removal of saw dust wood shavings, binding wire, rubbish, dirt, etc. Openings shall be placed or holes drilled so that these materials and water can be removed. Such openings/holes shall be later suitably plugged. The various trades shall be permitted ample time to install drainage and plumbing lines, floor and trench drains, conduits, hangers, anchors, inserts, sleeves, bolts, frames and other miscellaneous embedded to be cat in the concrete as specified or required or as is necessary for the proper execution of the work.

All embedded parts, inserts, etc., supplied by the Corporation or the Contractor shall be correctly positioned and securely held in the forms, to prevent displacement during depositing and vibrating of concrete.

All anchor bolts shall be positioned and kept in place with the help of properly manufactured templates unless specifically waived in writing by the Employer's Representative.

Slots, openings, holes, pockets, etc., shall be provided in concrete work in the positions specified or required or as directed by the Employer's Representative.

Reinforcement and other items to be cast in concrete shall have clean surfaces that will not impair bond.

Prior to concrete placement all work shall be inspected and approved by the Employer's Representative and if found unsatisfactory, concrete shall not be poured until all defects have been corrected.

Approval by the Employer's Representative of any and all materials and work as stated herein shall not relieve the Contractor from his obligation to produce finished concrete in accordance with the requirements of the specification.

5.25.3.1 *Rain or Wash Water*

No concrete shall be placed in wet weather or on a water covered surface. Any concrete that has been washed by heavy rains shall entirely removed, if there is any sign of cement and sand having been washed away from the concrete mixture. To guard against damage which may be used by rains, the works shall be covered with tarpaulins immediately after the concrete has been placed and compacted before leaving the work ended. Any water accumulating on the surface of the newly placed concrete shall be removed by approved means and no further concrete shall be placed thereon until such is removed. To avoid flow of water over/around freshly placed concrete, suitable drains .and sumps shall be provided.

5.25.3.2 *Bonding Mortar*

Immediately before concrete placement begins, prepared surfaces except formwork, which will come in contact with the concrete to be placed, shall be covered with a bonding mortar as specified.

5.26 Standards

Materials and workmanship shall comply with the relevant Indian Standards (with amendments) current on the date of submission of the tender. Where the relevant standard provides for the furnishing of a certificate to the Engineer, at his request, stating that the materials supplied comply in all respects with the standard, the Contractor shall obtain the certificate and forward it to the Engineer. The specifications, standards and codes listed below are considered to be part of these specifications. All standards, specifications, codes of practices referred to herein shall be the latest editions including all applicable official amendments and revisions. In case of discrepancy between the Specifications and the Standards referred to herein, the Specifications shall govern.

5.26.1 **Materials**

IS:269 Specification for 33 grade ordinary Portland cement

IS:278 Specification for Galvanized Steel Barbed Wire for Fencing

IS:383 Specification for coarse and fine aggregates from natural sources for concrete

IS:428 Specification for distemper, oil emulsion, colour as required

IS:432 Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement (Parts 1 & 2)

IS:455 Specification for Portland slag cement

IS:458 Specification for precast concrete pipes (with and without reinforcement)

IS:650 Specification for standard sand for testing of cement

IS:651 Specification for salt glazed stoneware pipes and fittings

IS:808 Specification for dimensions for hot rolled steel beam, column channel and angle sections

IS:814 Specification for covered electrodes for manual metal arc welding of Carbon and Carbon Manganese steel

IS:1003 Specification for timber paneled and glazed shutters (Parts 1 & 2)

IS:1038 Specification for steel doors, windows and ventilators

IS:1077 Specification for common burnt clay building bricks

IS:1398 Specification for packing paper, water proof, bitumen laminated

IS:1489 Specification for Portland pozzolana cement (Parts 1 & 2)

IS:1566 Specification for hard drawn steel wire fabric for concrete reinforcement

IS:1580 Specification for bituminous compounds for water proofing and caulking purposes

IS:1786 Specification for high strength deformed steel bars and wires for concrete reinforcement

IS:1852 Specification for rolling and cutting tolerances for hot rolled steel products

IS:1948 Specification for aluminum doors, windows and ventilators

IS:1977 Specification for structural steel (ordinary quality)

IS:2062 Specification for steel for general structural purposes

IS:2140 Specification for Stranded Galvanized Steel Wire for Fencing

IS:2185 Specification for concrete masonry units (Parts 1 & 2)

IS:2202 Specification for wooden flush door shutters (Parts 1 & 2)

IS:2645 Specification for integral cement water proofing compounds

IS:2750 Specification for steel scaffoldings

IS:2835 Specification for flat transparent sheet glass

IS:3384 Specification for bitumen primer for use in waterproofing and damp proofing

IS:3502 Specification for steel chequered plates

IS:4021 Specification for timber door, window and ventilator frames

IS:4350 Specification for concrete porous pipes for under drainage

IS:4351 Specification for steel door frames

IS:4990 Specification for plywood for concrete shuttering work

IS:8112 Specification for 43 grade ordinary Portland cement

IS:9862 Ready mixed paint, brushing, bituminous, black, lead free, acid, alkali, water and chlorine resisting

IS:10262 Recommended guidelines for concrete mix design

IS:12269 Specification for 53 grade ordinary Portland cement

IS:12330 Specification for sulphate resisting Portland cement

5.26.2 **Tests**

IS:516 Method of test for strength of concrete

IS:1182 Recommended practice for radiographic examination of fusion - welded butt joints in steel plates

IS:1199 Methods of sampling and analysis of concrete

IS:2386 Methods of test for aggregates for concrete (Parts 1 to 8)

IS:2720 Methods of test for soils (Parts 1 to 39)

IS:3025 Methods for sampling and test (physical and chemical) for water and wastewater (Parts 1 to 59)

IS:3495 Method of test for burnt clay building bricks (Parts 1 to 4)

IS:3613 Acceptance tests for wire flux combination for submerged arc welding

IS:4020 Methods of tests for wooden flush doors shutters: Type tests

IS:4031 Methods of physical tests for hydraulic cement (Parts 1 to 15)

IS:5807 Method of test for clear finishes for wooden furniture (Parts 1 to 6)

IS:7318 Approval tests for welders when welding procedure approval is not required (Parts 1 and 2)

IS:13311 Methods of Non-destructive testing of Concrete: Part 1 & Part 2

5.26.3 **Codes of Practice**

IS:456 Code of practice for plain and reinforced concrete

IS:783 Code of practice for laying of concrete pipes

IS:800 Code of practice for general construction in steel

IS:806 Code of practice for use of steel tubes in general building construction

IS:816 Code of practice for use of metal arc welding for general construction in mild steel

IS:817 Code of practice for training and testing of metal arc welders

IS:875 Code of practice for design loads (other than earthquake) for building structures (Parts 1 to 5)

IS:1081 Code of practice for fixing and glazing of metal (steel and aluminum) doors, windows and ventilators

IS:1172 Code of practice for basic requirements for water supply, drainage and sanitation

IS:1477 Code of practice for painting of ferrous metals in buildings (Parts 1 & 2)

IS:1597 Code of practice for construction of stone masonry (Parts 1 & 2)

IS:1742 Code of practice for building drainage

IS:1893 Criteria for earthquake resistant design of structures (Part 1)

IS:1904 Code of Practice for Design and Construction of Foundation in Soils: General Requirements.

IS:1948 Specification of aluminum doors, windows and ventilators

IS:2065 Code of practice for water supply in buildings

IS:2204 Code of practice for construction of reinforced concrete shell roof

IS:2210 Code for design of reinforced concrete shell structures and folded plates

IS:2212 Code of practice for brickwork

IS:2338 Code of practice for finishing of wood and wood based materials (Parts 1 & 2)

IS:2394 Code of practice for application of lime plaster finish

IS:2395 Code of practice for painting, concrete, masonry and plaster surfaces (Parts 1 & 2)

IS:2470 Code of practice for installation of septic tanks (Parts 1 & 2)

IS:2502 Code of practice for bending and fixing of bars for concrete reinforcement

IS:2571 Code of practice for laying in-situ cement concrete flooring

IS:2595 Code of practice for radiographic testing

IS:2751 Recommended practice for welding of mild steel plain and deformed bars for reinforced construction

IS:2974 Code of practice for design and construction of machine foundations (Parts 1 to 4)

IS:3114 Code of practice for laying of Cast Iron pipes

IS:3370 Code of practice for concrete structures for the storage of liquids
(Parts 1 to 4)

IS:3414 Code of practice for design and installation of joints in buildings

IS:3558 Code of practice for use of immersion vibrators for consolidating concrete

IS:3658 Code of practice for liquid penetrant flaw detection

IS:3935 Code of practice for composite construction

IS:4000 Code of practice for High strength bolts in steel structures

IS:4014 Code of practice for steel tubular scaffolding (Parts 1 & 2)

IS:4111 Code of practice for ancillary structures in sewerage system (Parts 1 to 4)

IS:4127 Code of practice for laying of glazed stoneware pipes

IS:4326 Code of practice for Earthquake Resistant Design and Construction of Buildings

IS:4353 Recommendations for submerged arc welding of mild steel and low alloy steels

IS:5329 Code of practice for sanitary pipe work above ground for buildings

IS:5334 Code of practice for magnetic particle flaw detection of welds

IS:5822 Code of practice for laying of welded steel pipes for water supply

IS:7215 Tolerances for fabrication of steel structures

IS:9595 Recommendations for metal arc welding of carbon and carbon manganese steels

IS:10005 SI units and recommendations for the use of their multiples and of certain other units

5.26.4 **Construction Safety**

IS:3696 Safety code for scaffolds and ladder (Parts 1 & 2)

IS:3764 Safety code for Excavation work

IS:7205 Safety code for erection of structural steel work

IS:3696 Safety code for scaffolds and ladder (Parts 1 & 2)

IS:3764 Safety code for Excavation work

IS:7205 Safety code for erection of structural steel work

5.27 General Arrangement of Plant

The following general guidelines shall be followed in the preparation of general arrangement of Plant:

(i) Sufficient room shall be allowed between components of plant and adjacent Plant or fixed structures to permit safe and convenient access for operation and maintenance.

(ii) An area adjacent to all mechanical Plant shall be provided as maintenance lay down area.

(iii) Fixed runways, lifting eyes or other means shall be provided to permit the removal of Plant that may be required to be removed during the course of its normal operational life for maintenance or any other purpose.

(iv) Areas where leakage is likely to occur, whether in normal use or during maintenance, shall be provided with covered drainage channels which shall direct spillage either to a suitable plant drain or to a sump from where it can be pumped to plant drain.

5.27.1 Buildings and Structures

All the building and structure works shall generally comply with the following requirements, unless otherwise specified elsewhere.

1. All building works shall be of reinforced concrete framework.
2. All external walls shall be in solid cement concrete blocks or brick masonry. Concrete Blocks shall be provided as per IS:2185 (Latest Revision) and shall be 200 mm thick or Brick masonry with one Brick thick (230 mm). Solid Concrete blocks shall have minimum compressive strength of 5 N/mm^2.
3. All internal partition walls shall be in solid concrete blocks or brick masonry. Concrete block shall be provided as per IS:2185 (Latest Revision) or Brick masonry with Half Brick thick (115 mm). Solid Concrete blocks shall have minimum compressive strength of 5 N/mm^2.All internal walls shall be 200/230mm thick except for toilets. Toilet partition walls shall be in 100/115 mm thick solid concrete block/brick.
4. (a) Finishes to concrete liquid retaining structures shall be:

   F2 External surfaces, buried

   F3 External surfaces exposed and up to 300 mm below ground level

   F2 Internal surfaces

   (b) Finishes to other concrete structures shall be:

   F2 Buried

   F2 Exposed, where plastering is specified

   F3 Exposed
5. All internal masonry surfaces finish shall have 12 mm thick plain faced cement plaster in cement mortar (1:4) with neat cement finish on top. Over this, one coat of primer and two coats of plastic emulsion paint of approved quality and shade shall be provided.
6. All external masonry surfaces and concrete surfaces with rough board finish shall have 20 mm thick sand faced cement plaster in two coats, base coat 12 mm thick in cement mortar 1:4 and finishing coat 8 mm thick in cement mortar 1:4. Waterproofing compound of approved make and quality shall be added to the cement mortar in proportions as specified by the manufacturer.
7. All external surfaces above ground level shall have one coat of primer and two coats of waterproof cement based paint of approved quality and shade. A coat of silicone water repellent paint shall also be applied thereon.
8. Toilet areas, internal walls tiled up to 1.5m and rest and ceilings, shall have one coat of

primer and two coats of plastic emulsion paint.

9. Toilet floor slab shall be filled with brick bat coba (broken bricks in lime) and provided with waterproofing as per the specifications of an approved specialist waterproofing company.
10. The finished floor level in toilet areas shall be 25 mm below general finished floor level elsewhere in the building.
11. The flooring in all other areas except control building, chemical building, store building, pump station buildings and toilets and staircases shall be in 450 mm x 450 mm x 25 mm thick polished Kota-stone of approved shade and pattern and placed in cement mortar to give overall thickness of 50 mm. Half tile skirting shall also be provided in these areas.
12. The flooring along with skirting in administration and control building shall be 20 mm thick mirror polished, machine cut granite slab of approved shade and pattern placed in cement mortar (1:4). Skirting for 150mm height shall be provided in these areas. Granite stone shall be provided for laboratory platforms fixed over double sandwiched cuddappah support as directed and the edges of granite is to be embedded into the wall.
13. The flooring in chemical building shall be of ceramic unglazed vitreous acid resisting tiles.
14. Pumping station buildings shall have cement concrete flooring with surface hardener.
15. All Chemical buildings shall have heavy-duty abrasion resistant tile flooring.
16. Toilet areas shall have glazed ceramic vitrified tiles placed in cement mortar 2000 mm high dado, in 150 mm x 150 mm x 6 mm thick glazed tiles placed in cement mortar shall also be provided in these areas.
17. The toilet facilities in control building shall include at least:
    - (i) 2 Nos. water closets with white porcelain Orissa pan minimum 580 mm long with flushing cistern of 10 liters capacity.
    - (ii) 2 Nos. urinals of sizes 600 mm x 400 mm x 300 mm flat back type in white porcelain separated by a marble partition of size 680 mm x 300 mm with flushing water piping with water taps.
    - (iii) 2 Nos. wash basins of size 510 mm x 400 mm in white porcelain with inlet, outlet and overflow arrangements.
    - (iv) 2 Nos. mirror of size 400 mm x 600 mm wall mounted type fitted over wash basins.
    - (v) 2 Nos. plastic liquid soap bottles
    - (vi) 2 Nos. chromium plated brass towel rails minimum 750 mm long.
    - (vii) All stopcocks, valves and pillar cocks shall be heavy duty chromium plated brass.
    - (viii) All fittings such as \`P' or \`S' traps, floor traps, pipes, downtake pipes etc.
    - (ix) The sewage from toilet blocks shall be led to a septic tank.
18. In control building a canteen facility shall be provided with a washbasin, a sink, required

electrical points, exhaust fan, an electric water heating pot, a micro-oven and a fridge as a minimum.

19. All staircases except in the buildings, shall have 25 mm thick polished Kotastone tiles for treads and 25 mm thick of approved shade for treads & risers set in cement mortar or lime mortar to give an overall thickness of 50 mm. Stairways with 1.5 m width shall be provided to permit access between different levels within buildings. All roof tops and overhead tanks shall be made accessible with ladder provision with SS316 hand rails. Vertical ladders fitted with landing point extensions will be permitted where approved by the Engineer to access areas not frequently visited. Plaster encapsulated Cast Iron/ GRP rungs or steps shall be provided on the inner side walls of all the water retaining structures at 300mm spacing.
20. All floor cut-outs and cable ducts, etc. shall be covered with precast concrete/GRP covers in outdoor areas and epoxy costed mild steel chequered plates of adequate thickness in indoor areas. All uncovered openings shall be protected with GI pipe hand railing 32 mm GI inside dia medium class with approved paint.
21. All staircases shall be provided with Stainless Steel 316 hand railing for protection. In existing structures damaged hand railing shall be replaced.
22. The reinforced concrete roofs shall be made waterproof by water proofing as approved by the Engineer. The finished roof surface shall have adequate slope to drain quickly the rain water to R.W down take inlet points.
23. For roofing drainage, cast iron rainwater downtake with C.I/uPVC. bell mouth and C.I./uPVC grating at top shall be provided. For roof areas up to 40 sq.m minimum two nos. 100 mm diameter downtake pipes shall be provided. For every additional area of 40 sqm or part thereof, at least one no. 100 mm dia. downtake pipe shall be provided.
24. Top surfaces of chajjas and canopies shall be made waterproof by providing a screed layer of adequate slope and sloped to drain the rain water.
25. Building plinth shall be minimum 450 mm above average finished ground level around building. Wherever cable trench shall be provided below the electrical panel, Bottom level of the cable trench shall be 100mm above the plinth level.
26. All doors, windows, rolling shutters shall have lintels above. Chajja protection to lintels on external walls shall be such as to prevent the rain water splashing into the building. Chajja projection of minimum 750 mm for rolling shutters, 600 mm for doors and 450 mm for windows shall be provided to prevent the rain water splashing into the building. Chajja shall be projected 150 mm on either side from size of doors/windows/rolling shutters.
27. All windows and ventilators shall have 25 mm thick Granite stone sills bedded in cement mortar (1:3) or 38 mm M15 CC or as per flooring material.
28. All doors, windows and ventilators shall be made of aluminium confirming to latest version of IS:1948. All fixtures for doors, windows and ventilators shall also be of aluminium and shall be provided as per IS specifications. Aluminium grills shall be provided in all the windows. Doors shall be in two panel and both panels shall be glazed/unglazed. SS wire mesh shall be provided along with aluminium grills.

29. Openings of the windows & ventilators shall be minimum 25% of the wall area.
30. Ventilator shall also be provided where height of floor is more than 3m. All windows and ventilators shall have SS wire mesh. Frame of doors, windows and ventilators shall be of aluminium of standard rolled section. Doors, Windows and Ventilators shall be of size as per schedule to be submitted by the Contractor for approval of the Engineer. The minimum size shall be as per below:

    Door of opening size 1.2m x 2.1m

    Door of opening size 0.75m x 2.1m for toilets

    Glazed windows of minimum size 1.2m x 1.2m

    Ventilators of minimum size 0.6m x 0.6m
31. Rolling shutters shall be made of 80 x 1.25 mm MS laths. Rolling shutter shall be of minimum size 3m wide x 3.0m high. Rolling shutter shall be provided in MCC cum panel room, all chemical buildings, at entry and exit of the pump house for access to pumps, motors, valves, panels and as wherever required.
32. All structural steel members shall be painted with two coats of enamel paint over one shop and one field coat of red oxide zinc chrome primer.
33. All concrete channels and ducts used for conveying liquid shall have inside finish of type F2. The width of concrete channels shall not be less than 500 mm. All open channels shall be provided with Type 304 stainless steel hand railings.
34. Kerbs to be provided below the hand railing on the catwalks/pathways should be as per relevant sections of Factory Act.
35. All rooms in the treatment plant buildings shall be provided with appropriate sign boards of approved material indicating the function of the rooms involved.
36. Wherever equipment and machinery are to be moved for inspection, servicing, replacement etc., suitable movable gantry of minimum capacity of 2 tonnes or more as required shall be provided with monorail and operating equipment.
37. The design of buildings shall reflect the climatic conditions existing on site. Process buildings shall as far as possible permit the entry of natural light, and the use of glazed panelling shall be kept to a minimum and preference given to wall openings protected by weather canopies.
38. Emergency exit doorways and safety features shall be provided from all buildings in order to comply with local and international regulations. Stairways and paved areas shall be provided at the exit points.
39. Toilet blocks in process buildings and control blocks shall be provided with a sink with two drinking water taps of 20 mm size with adequate inlet and outlet connections.
40. The side walls of buildings shall, except those used for storage and handling of chlorine, comprise at least 15% ventilated brickwork or louvers. Ventilated brickwork or louvers shall not be used where the ingress of driven rain could affect plant or stored materials.

Flat roofed areas shall be provided with roof vents to further encourage a through flow of air.

41. All the walkways shall have minimum 1.0 m width and shall be covered with cement chequered tiles.
42. Hand railings shall be 38 mm pipe made up of SS316. Height of railing not less than 1100mm.The distance between 2 vertical posts shall not be more than 1.8 metres. This shall also match with existing hand railing.

5.27.2 **Roads, Pathways & Hard standings**

A comprehensive network of roadways shall be provided around the site and permit access to the plant for necessary maintenance, delivery of consumables and personnel access. All roads shall be of asphalt macadam and minimum 5 meters wide and as per width indicated in the attached plant layout. Vehicular access shall be provided for all Plant structures and buildings. All roads shall be provided with drainage and shall be constructed to prevent standing water.

Paved pedestrian access ways shall be constructed to provide a network of logical routes interlinking plant areas. Damage to any existing roads on account of their use by the Contractor shall be made good to the satisfaction of the Engineer.

Hard standing areas shall be provided to permit the parking of vehicles involved in the delivery of consumables from blocking site roadways during unloading or loading. The road system shall be designed such that vehicles involved in the delivery of consumables can follow a continuous route through the works and out again without the need to reverse or carryout complicated maneuvers in order to exit the site.

5.27.3 **Site Drainage**

The contractor shall provide a site drainage system. The system shall comprise of the following:

- Storm Water Drainage
- Foul Drainage
- Process Drainage

All waste water after treatment shall be drained in the plant Outfall Tank for discharge to the sea.

5.27.3.1 *Storm Water Drainage*

Storm water drains adjacent to the existing and proposed roads (under this Contract) shall be sized for a rainfall intensity of minimum 50 mm/hr, allowing for 100% runoff. Drains adjacent to roads shall be either with RCC floor and walls in M-20 concrete with minimum 150 mm thickness or in stone masonry (1:4) of appropriate thickness, topped with 75 mm thick M 15 concrete and 20mm thick plaster on internal surfaces in cement mortar (1:4). The minimum width of drain shall be 450mm wherever not existing and needed.

The storm water drainage system shall be designed to cater for the run-off from the existing water plants treatment areas and structures.

5.27.3.2 *Foul Drainage*

The foul drainage system shall accept discharge from toilets, washrooms, offices and the laboratory. The foul drainage system shall be directed to the sewage treatment plant provided by the Contractor for appropriate capacity as indicated in the Part-2, A3 document. The rainwater and treated domestic water shall be used for toilet flushing and irrigation around the plant site.

5.27.3.3 *Process Drainage*

Under this project, all the wastewaters at the plant including backwash wastewater from the Dual Media Filters will be directed to the Outfall Tank for discharge to sea. No discharge will directly go to the sea. All wastewaters (domestic and industrial) must be treated first to meet the surface discharge requirements as per the concerned regulatory guidelines before discharge to the sea via the outfall tank. The Contractor shall plan the pipeline alignment, draw longitudinal section of the pipeline showing the ground levels, pipe invert levels etc., and get approval from the Engineer prior to start of the work.

The Contractor shall provide all the services including interconnections of the drain pipes, site clearance with cutting of the trees, shrub etc. coming in the drain line alignment, excavation to the required level for the pipeline, bed preparation including required bed strengthening, laying and jointing of the pipeline, back filling etc. Manhole chambers shall be provided at every junction and bends and at 45 m interval on straight reaches.

5.27.4 **Cable and Pipe Work Trenches**

Cable and pipe work trenches shall be constructed in reinforced concrete. However, 500 mm x 500 mm size or smaller trenches, not on fill may be constructed in Bricks/Concrete Blocks. The trenches shall be plastered internally with cement mortar (1:4) and externally in cement mortar (1:3).

Trenches within the buildings shall be covered with M.S chequered plates, suitably epoxy painted and those outside the buildings shall be covered with M20 precast R.C.C or more suitable material as per the consent of the Engineer. The trenches shall be suitably sloped to drain rain water.

Layout of trenches outside the buildings shall allow space for construction of future trenches where necessary with due consideration for planning for future developments. This aspect shall be brought to the notice of the Engineer while planning the works.

5.27.5 **Pipes and Ducts**

Reinforced concrete ducts/pipes for drainage shall have a minimum 1 metre cover while laid under roads. Access shafts of suitable size shall be provided. All drains shall be covered with precast reinforced concrete slab and designed structurally for appropriate loads. All interconnecting piping and channels in the plant shall be as per the requirements and as per specifications.

5.27.6 Valve and Flow meter Chambers

All the valves and flow meters shall be placed in the chambers as much as possible so that the ground surface remains available for free movement. The chambers are to be of adequate size to facilitate maintenance and operation. The base slab of chambers shall slope to drain the water to the common drain line or towards a sump pit from where water can be pumped out to a drain line to keep the chamber dry. The top of the valve chamber shall be 300mm above the FGL. All chambers shall be constructed in M20 reinforced concrete. Chambers shall have removable cast iron / reinforced concrete covers, as appropriate, with approach ladders and supports.

5.27.7 Pipeline Material

Due to saline environment, GRP/HDPE pipes of suitable schedule shall be used for the process at the plant. The use of mild steel pipelines shall be avoided and wherever provided in the plant with the consent of the Engineer shall be submerged arc welded with steel grade of Fe 410, conforming to IS:3589. The pipes shall have internal epoxy coatings and external polyurethane and epoxy coatings as approved by the Engineer. Polyurethane coatings shall be provided in 2 coats with total thickness not less than 500 microns over suitable primer coat. The thickness of pipes shall be adequate for internal pressure and external loading including live loads. In no case the thickness shall be less than the minimum specified in IS:3589.

5.27.8 Landscaping

The site shall be landscaped once the Works are substantially complete. Landscaping area shall be marked in layout plan. Landscaping shall include planting of suitable trees and development of grassed areas. Landscaping in general shall meet ecological and environmental conditions of the Site. Road widths shall determine the size of the tree height and spread to be selected for planting. Trees suitable for local conditions shall be selected. Plantation shall be started just after approval of the plant layout so that the plants become of good size at the completion of the capital works and start of the production at plant. Medicinal and fruit trees shall be avoided. Landscaping shall be maintained in good condition until the completion of Contract.

5.27.9 Tree Planting

Pits dug a few days in advance of actual planting shall be allowed to weather and be filled with top soil mixed with manure. Size of the pit shall be as per standard requirement. Only one tree shall be planted in each pit. A guard made of bamboo with wire mesh or bricks or MS rings as approved by the Engineer shall be provided.

5.27.10 Hydraulic Testing of Liquid Retaining Structures

In addition to the structural test of the structures, the liquid retaining structures shall also be tested for water tightness test at full supply level as described in 10.1.1,10.1.2 and 10.1.3 of latest revision of IS:3370 (Part I).

On completion of the structure and before its commissioning, the contractor shall carry out a water tightness test for the maximum water head condition with the water standing at full supply level (FSL). This test shall be carried out preferably in dry season in accordance with the procedure given below.

The water tightness test shall be carried out when the construction of liquid retaining structure is completed and when it is possible to fill the structure and ensure that uniform settlement of the structure as a whole or as directed by the Engineer. Before the filling operations are started the structure shall be inspected by the Engineer/Engineer's Representative and the Contractor's Representative and the condition of surfaces of walls, contraction joints shall be noted and it shall be ensured that the jointing material filled in the joint is in position and all openings are closed. The Contractor shall make necessary arrangement for ventilation and lighting of the structure by way of floodlights, circulators etc. for carrying out proper inspection of the surfaces and inner conditions if so desired by the Employer. Records of leakages starting at different levels of water in the reservoir, if any, shall be kept.

The liquid retaining structure once filled shall be allowed to remain so for a period of seven days before any readings of drop in water level are recorded. The level of the water shall be recorded against the subsequent intervals of 24 hours over a period of seven days. The total drop in surface level over a period of seven days shall be taken as an indication of the water tightness of the structure, which for all practical purposes shall not exceed 40 mm. Also, there shall be no indications of the leakages around the opening or on the walls.

If the structure does not satisfy the condition of test and the daily drop in water level is decreasing, the period of test may be extended for a further period of seven days and it the specified limit is then reached the structure may be considered as satisfactory.

The external faces of structure shall not show any signs of leakage and shall remain apparently dry over the period of observation of seven days after allowing a seven-day period for absorption after filling.

In case the drop in level exceeds the permissible level limit and signs of leakage with the stipulated period of test, the Contractor shall carry out such additional works and adopt such measures as may be directed by the Engineer/Engineer's Representative to reduce the leakage within the permissible limits. The entire rectification work that shall be carried out in this connection shall be at the Contractor's cost. The water required for subsequent testing shall be supplied to the Contractor free of cost, if the same is available near the site. Contractor shall have to make arrangement for filling emptying the structure at his own cost.

If the test results are unsatisfactory, the Contractor shall ascertain the cause and make all necessary repairs and repeat the water retaining structures test procedures, at his own cost. Should the re-test results still be unsatisfactory after the repairs, the structure will be condemned and the Contractor shall dismantle and reconstruct the structure, to the original specification, at his own cost.

During testing and during defect liability period the impression marks created due to seepage shall be rectified and made good. No separate payment shall be made for water tightness test and the cost thereof shall deem to be covered in the rates quoted for the works.

5.27.11 **Non Destructive Testing of Reinforced Concrete Structures**

Non-Destructive Testing (NDT) shall be carried out as per latest IS:13311 codes as per the instructions given by the Engineer.

5.27.12 **Site Clearance**

The Contractor shall cut the trees, remove the shrubs and grass prior to marking the plant layout on the ground. Prior to cutting of the trees, permission of the concern authority as needed must be obtained by the Contractor for which required official help may be extended by the Engineer. Counting of the trees shall be done by the Contractor in presence of the Engineer's Representative. The cut trees shall be handed over to the CMWSSB. The Contract cost shall cover the job of site clearance as required and no separate payment shall be allowed against this job.

5.28 MATERIALS

5.28.1 **CEMENT (ORDINARY AND PORTLAND)**

All Portland Cement for use on the works shall comply in every respect with requirements of the Indian Standard Quality of Cement Specification for Portland Cement as issued and amended from time to time by the Indian Standards Institution. The Portland Cement used in the works shall be manufactured in India and shall be of a make and quality to be approved by the Engineer.

No other make/grade of cement, but that approved by the Engineer will be allowed on the works and the contractor shall not change his source of supply without the approval of the Engineering in writing.

Tests ⇒ Produce test certificates to show that the cement is fully up to the specification and notwithstanding this, the Engineer may at his discretion order that the cement delivered on the work and which he may consider damaged or of doubtful character for any reason whatsoever, must be retested by approved testers and fresh certificates of its soundness produced by the contractor at his sole cost. Cement ordered for re-testing shall be withdrawn from the work pending the results of re-testing. The decision of the Engineer in this respect shall be final binding on the Contractors.

Stores ⇒ Large stock of cement shall not be kept at the works but sufficient quantities to ensure continuity of the work. The contractors shall provide and maintain proper and sufficient storage sheds for the cement on the works. The floor of the stores shall be raised at least 9" from the ground in order to protect the bags from moisture. No cement damaged exposure or otherwise will be allowed to be used in work, but shall be removed at once from the site.

Packages ⇒ the cement shall be supplied in sound and properly secure sealed bags, weighing (1 bag) 50 kg. Net. The rates entered in the Bill of Quantities and Rates shall be held to include the cost of haulage to the work housing and protecting from the weather, risks of every kind and all expenses connected with preparing the cement for use and with using it in the work.

5.28.2 **Sand**

All the sand aggregate shall consist of clean, hard, strong, durable quality of river sand uncoated, well-graded particles when incorporated in the concrete mixture, the fine aggregate shall be free from frost, frozen lumps injurious amounts of dust, mica loam or other deleterious substances.

The sand shall be of river and taken from a source approved by the Engineer. If the Engineer considers if necessary, it shall be washed. The cost of washing must be included in this price for the concrete work.

All sand shall pass through a sieve having meshes not more than (1/4" inch) 6 mm. Wide and if the Engineer shall require it, it shall be screened before use at the expense of the contractor. In no case shall fine aggregate be accepted containing more than two percent, dry weight, not more than three and half percent by dry volume of clay, loam or silt. If any sample of fine aggregate show more than five percent of day, loam silt in one hour's settlement, after shaking in an excess of water, the material represented by the sample will be rejected. If necessary, silt test shall be taken by the Engineer.

All fine aggregate shall be stored on the works in such a manner as to prevent the intrusion of foreign matter. The fine aggregate shall confirm to IS 383 (latest).

5.28.3 **Coarse Aggregate**

The whole of the ingredients of the coarse aggregate shall be Quality coarse consisting of crushed rock, gravel or other aggregate material. The particles of coarse aggregate shall be clean, hard, tough, durable material, free from vegetable or other deleterious substances and shall contain no soft flat or elongated pieces. All coarse aggregate shall be stored on the works in such a manner as to prevent the institution of foreign matter. If it is considered necessary, the Engineer may order it to be washed and screened. The contractor shall state in his tender the source from where he will obtain the aggregate and he shall also include in his price the cost of washing. If screening is necessary and the cost shall be borne by the contractor.

The coarse aggregate shall consist of:

Grading of Coarse: 1.

1	Metal No.2	¾" to 1"	20 to 25 mm. Aggregate
2	Metal No. 1	¼" to ½"	6 to 12 mm

The whole of the aggregate shall all pass a screen having meshes not greater than 1" (2.54 cm.) square and shall be retained on a screen having meshes ¼" (6.35 mm) square. The materials may be tested for voids before the work is commenced and at intervals during the coarse of construction, as may be necessary and the proportion of the different grades in the coarse aggregate fixed by the Engineer so as to secure a well graded material varying from (1/4" to 1") 6.35 mm to 25.4 mm. The different grades of the coarse aggregate shall be measured by means of suitable boxes and in such proportion as may be approved by the Engineer.

5.28.4 **Water**

The water shall be clean and free from injurious amounts of oil, acid, alkali, organic or other deleterious substances. The quality of water added to the materials for making concrete shall be properly under control and must be measured.

5.28.5 **Reinforcement**

The steel to be used in reinforced concrete work shall comply with the requirements of Indian Standard Specification I.S. No. 43 (Latest) for saline water use.

If any steel does not in the opinion of the Engineer comply with any of the tests specified for the saline water environment, the Engineer may reject the lot or lots from which the sample or samples taken and the same shall not be used on the works but shall be removed from there.

All steel used for reinforcement shall be free from loose scales or rust, which must be removed with a stiff wire brush. Bars must also be free from oil or paint. The steel should be properly braced, supported and otherwise held in position strictly according to the contract and plans. This shall be looked after with proper care and checked over by a competent foreman personally and finally before pouring the concrete.

5.28.6 **Polymers**

The polymer modifier shall be a modified acrylic based compound suitable for use in marine environment. The product shall have minimum solids of 40% $\pm$ 2%. The polymer shall be capable of being used both as a bonding agent having a pull off bond strength not less than 1 Mpa and also as an additive for preparation of polymer modified repair mortar.

5.28.7 **Coal Tar Epoxy**

It shall be high build pitch extended epoxy coating and shall be 100% solids, solvent free, tough abrasion resistance coating.

The product shall exhibit excellent bond strength with substrate exceeding 2.5Mpa as per ASTMD4541.

The product shall be formulated to have high build thickness exceeding 150 microns per coat on average to achieve overall thickness of 300 micron in 2 coats.

The product shall be formulated to resist exposure to accelerated weathering test as per ASTMD4587 and shall not exhibit any flaking or blistering.

5.28.8 **Epoxy**

The Non Toxic High build epoxy coating shall be solvent free, taint free, potable grade protective coating. The product shall exhibit bond strength exceeding 1.5Mpa tested as per ASTMD4541. Product shall be formulated to have a thickness of 200 microns per coat on average to achieve overall thickness of 400 microns in 2 coats. Product shall be approved by CTRI for use in contact with potable water.

5.28.9 **Waterproofing Membrane**

Self adhesive elastomeric SBS bitumen based waterproofing membranes with high mechanical performance polypropylene mesh, finish of upper side and easily removable silicone film on underside. Thickness of membrane shall be minimum 1.5mm.

5.28.10 **Polypropylene Fibres: (For Concrete work / Mortar Work)**

The material shall be virgin high tenacity polypropylene mesh fibre and multifilament combination in 10mm length for use in water retaining structures concrete work.

Dosage should be minimum 125gms/bag of concrete as per specified dosage of Consulting Engineer.

The fibres shall be Alkali and Acid resistance, non absorbent, and chemically Inert having a density of 0.93gms/cc and should confirm to ASTM C-1116. Lengths of strands shall be 10mm blended for plaster work Dosages shall be 100g/bag of cement.

5.28.11 **Glass Fibres**

The Glass fibres shall be Alkali Resistance Glass fibre specially developed for Cementatious Mortars and Concrete Mixes.

They shall be monofilament having diameter of 14µ and a specific gravity of 2.6, length 12mm and an Aspect ratio of 857:1 and a specific surface area of 105m^2/Kg.

Dosage shall be minimum = 85g/per bag of cement but to be decided by the Consulting Engineer in charge.

5.28.12 **Plasticizers**

The liquid integral waterproofing shall be lignosulporiate Polymer based waterproofing cum plasticizing admixture. The product shall comply with IS 2645:2005 when tested at a dosage of 100ml/50 kg bag of cement. The product must be free of chlorides and shall have a specific gravity of not less than 1.15 and shall comply to ASTM C 494 type A & D.

5.28.13 **Pre-packed Ready Made Plasters**

The Prepacked ready-made plasters shall be coarse / fine water resistance mortar for internal / external use.

The blend shall be made of fillers which are silt free precisely graded sand with OP cement as binder and additives to improve workability water retention durability and adhesion of mortar.

The blend shall have PP fiber in proportion not exceeding 125gms / 50kg cement and fly ash not exceeding 25% as substitution of cement.

5.28.14 Expansion Joint Sealing Tape

The joint shall be treated with a highly elastic (having elongation > 600%) and share a hardness of 80 with special epoxy as adhesives. The expansion tape shall be supported by single component gun graded quality PU sealant followed by a backing material of polyethylene.

Width of expansion joints shall not exceed 150mm. Thickness of joint sealing tape shall be minimum 2mm.

The tape shall have tensile strength exceeding 6Mpa and resistance to cracking exceeding 600N/cm when tested as per DIN 53363.

5.29 SURGE CONTROL SYSTEMS

5.29.1 Design of Control System

Surge analysis for the sea water intake and pure water main, along with the design and provision of the required surge protection devices, shall be the responsibility of the Contractor. The surge control systems shall be designed so as to ensure that:

- the maximum residual surge shall be restricted to 10% of the maximum surge which would have developed without the surge control devices at any point in the pipeline or 10% of the design pump head, whichever is more; and
- the vacuum pressure developed in the pipeline at any place shall be restricted to –3 m (minus 3 meters); and
- the surge protection system provides adequate protection against damage for the valves, pipe delivery systems and pumps.

The surge analysis and design for surge protection system shall be got done from the Indian Institute of Science, Bangalore, or any other qualified agency approved by Employer's Representative. The detailed designs and drawings of the surge protection system shall be submitted for the approval of the Employer's Representative, but any such approval shall not relieve the Contractor from his responsibility for the safety of the system.

The feasible surge protection system in such a case shall be in the form of one way surge tanks, surge shaft, air vessel or any other better system as approved by the Employer's Representative, or any other better system suggested by Contractor and acceptable to the Employer's Representative.

The Contractor shall also check the requirements for any protection devices downstream of the pipelines away from the intake to control negative pressures. The design shall be suitable to cater to the space requirements for the surge protection systems and the size of the available spaces.

The design agency shall finalize all particulars of the surge control system and submit calculations, including the number and capacity of air vessels, surge shafts, orifice plate diameters, interconnection details with pumping main, etc., depending on the adopted system. The detailed specifications for the proposed surge protection system along with designs shall be submitted for approval from the Employer's Representative.

The equipment used for the surge protection system must be procured from manufacturers who have previous experience of manufacturing such systems. The manufacturer shall submit certificates of test results for at least two systems manufactured and installed by him with for pumping mains of not less than 2000 mm diameter. For air vessels, the manufacturer must produce test results on at least two completed schemes with volume of the vessel larger than half the volume of vessel recommended by the surge designer for the Nagpur water supply system. In case of the surge shaft/tanks, all valves used shall be of reputed and accepted makes with proper opening characteristics.

5.29.2 **Pure Water Surge System**

The Contractor is cautioned that the constraints for installation of surge tanks/ pressure vessel are particularly severe in the pure water system. The pipeline to be protected is to be laid above ground on pedestals in the initial stretch, detached from the road. Besides this, space for laying and jointing of the pipeline and connecting the pipeline to the surge tank is restricted and constrained by the topography.

5.29.3 **Technical Specifications for Air Vessel System**

The technical specifications provided herein cover surge control systems with air vessels. This, however, is not intended to imply that a surge control system using air vessels is the best or only alternative to be considered; the Contractor will be fully responsible to analyze the requirements and recommend the type of surge control systems that are the most suitable and effective for the pure water pumping systems. In case any alternative surge protection system is recommended by the designer, he shall also submit the detailed specifications of the same for approval from the Employer's Representative.

5.29.3.1 *Air Vessel - General Specifications*

Air vessels should be suitable to take care of the water hammer/ pressure surges which may occur in the pipeline systems on which they are proposed. The air vessels shall be manufactured out of MS plates as per IS 2062. The nozzles shall be seamless conforming to SA 106 Grade B. Flanges up to 250 NB shall be of weld neck type of forged quality conforming to SA 105. The design and fabrication will be carried out as per latest version of IS 2825. At least 10% of the weld joints on the vessel shall be spot radio graphed. 100% of the weld joints, if any, on the dish shall be radio graphed. Air vessels will be provided with manholes and water outlets at the bottom, which will be connected to the rising mains along with an isolating valve and a differential orifice. Suitable drains are to be provided for maintenance. Air vessels will have standard fittings such as pressure relief valve, visual level indicators, control circuit inlets and outlets, etc., with isolating valves. Inspection for air vessels shall cover welding qualifications, radiography / UT / PT/ MT as applicable, Stage/ in-process inspection, and hydro/ leak tests.

Two air compressors shall be supplied along with each air vessel. These compressors will be operating at a slightly higher pressure than the pressure in the water main, and compressed air will be stored in the receiver from which requisite supply will be made to the air vessel. Inspection of compressors shall cover dimensional checks for mounting and overall dimensions, performance tests, and hydraulic leak tests.

The air vessel and air receiver will be painted internally and externally with zinc rich food grade epoxy paint.

The following additional equipment will be supplied as standard accessories for each air vessel:

- Receiver with compressor, with automatic on/off system.
- Visual water level indicator, covering full height or length of the air vessel.
- Isolating and drain valves for maintenance purpose

5.29.3.2 *Surge Suppression System*

The automatic control system shall be generally as described below. Contractor may propose alternative arrangement.

The surge protection system shall comprise of air compressors, common air receiver, surge vessel, field instruments and control panel with facilities for alarm annunciation and for operation and monitoring of compressor and air inlet valves of surge vessels. The surge vessels shall be connected with the common air header from the air receiver and at the base to the pumping station discharge header via the buffer manifold. The air inlet pipe to the surge vessels shall be provided with electrically / pneumatically operated valves to control air input to the surge vessels and an electrically / pneumatically operated valve to control air release from the surge vessel. For controlling the water level within the surge vessel, the vessel shall be provided with a conductivity type level switch. For continuous monitoring of water level within the surge vessel, capacitance type level measuring system shall be provided. A magnetic liquid level gauge shall also be provided to permit the visual monitoring of the water level in the surge vessels. The surge vessels shall be provided with safety air relief valve.

The electrically / pneumatically operated air inlet valve shall be provided in the air inlet line of the surge vessels to permit the entry and release of air from the surge vessels. Hand operated valves shall be provided in parallel with these valves for manual control of air addition and release.

5.29.3.3 *Normal Operation*

- The surge vessels are filled with water to a given level that is within a working level band. Air is added to the top of the surge vessels to act as a cushion and maintains the water level in the surge vessels within the working band. During normal operation, air will slowly dissolve in the water causing a gradual rise of the water level in the surge vessels.
- The mean working level (i.e. between upper working level and lower working level) is maintained constant by allowing more air from the compressor air receiver to enter the surge vessels.

- When the pumps stop supplying water to the discharge header (due to normal stopping, tripping, power failure, etc.) the non-return valve at the pump outlets will close. The water column continues to move away from the pumping station and in doing so will create a negative pressure in the discharge header.

- Water from the surge vessels is drawn into the discharge header through the surge non-return valve in order to limit the magnitude of this negative pressure and in doing so prevent damage to the pipe work. When water column reverses water enters the surge vessels through the NRV bypass line and the air in the surge vessels is compressed providing a cushioning effect to the returning water column. Energy of returning water column is absorbed due to compression of the air.

- The water level in the surge vessels shall be maintained within the working band during steady state pipeline flow conditions. The steady state water level in the surge vessels shall be maintained between the upper and lower working level settings.

- The limits of the bands between upper and lower working levels shall be fine tuned during commissioning.

- The status of the surge protection system and associated alarms shall be monitored at the ICP.

- The starting and stopping of the compressor shall be automatic with a manual override facility. The compressor shall start when there is a low air pressure in the associated air receiver and stop when the required air pressure is reached. Separate pressure switches shall be provided on air receiver for starting and stopping of compressor. The air receiver shall be provided with pressure gauge and safety relief valve.

- Conductivity type level switches shall be provided for monitoring the following levels in the surge vessel:

  - Upper emergency level
  - Upper working level
  - Mean working level
  - Lower working level
  - Lower emergency level

- The level switches shall be provided on the 'stand pipe' of the surge vessel. When the level in the surge vessel reaches the 'upper working level' and remains there for certain duration of time (adjustable), the pneumatic/ electric operated air inlet valve shall open. The valve shall close when the 'mean working level' is reached.

- When the level in the surge vessels reaches the 'lower working level' and remains there for certain duration of time (adjustable), the pneumatic/ electric operated air release valve shall open. The valve shall close when the 'mean working level' is reached.

- An orifice plate shall be provided to restrict the rate of air release to ensure restoration of the mean working level within approximately 30 minutes (to be decided during commissioning).

- A silencer shall be provided on the discharge to limit the noise made by air release. When 'upper emergency level' and 'lower emergency level' are detected by conductivity level switch, alarms shall be annunciated on the surge protection system control panel and on the main ICP. In addition water level high high and low low alarms shall be configured on the surge vessel water level analogue signal. These alarms will be used when the surge vessel water level is being controlled by hand such as when the surge vessel containing the level switches is taken out of service for maintenance. The high high and low low limits shall be set outside the digital alarm levels.
- Manual override facilities shall be provided for operating the compressor and the air inlet and air release valves. A non-return valve shall be provided on the air inlet line to the surge vessel to prevent back flow of water from the surge vessels to the air receiver.
  - A separate control panel shall be provided for operation and monitoring of the surge suppression system. The panel shall comprise the following:
  - Incoming isolator
  - Starters for compressors
  - Automatic-Off-Manual selector switch
  - Status indication
  - Start / stop pushbuttons for use in manual mode
  - Duty / standby compressor selector switch
  - Auto-manual selector switch for surge vessel air supply
  - Manual controls for air inlet and air release
  - Indication of surge vessel water level
  - Alarm annunciator to indicate the following alarms as a minimum
  - Surge vessel water level high
  - Surge vessel water level high
  - Surge vessel water level low
  - Surge vessel water level low
  - Compressor faults for each compressor as appropriate i.e. fail, oil temperature high, etc.
  - Low air pressure in receiver
  - All the critical alarms and signals required for safe efficient operation of pumping station shall be connected to the main PLC in ICP.

5.29.3.4 *Abnormal Operation*

- In case working compressor fails, the standby compressor shall come into operation automatically and an alarm shall be annunciated on surge suppression control panel and ICP.
- In case the control supply to surge suppression control panel fails an alarm shall be enunciated at the ICP and the operator shall carry out the operation of surge suppression system manually.

5.29.4 **Technical Specifications for Surge Tanks/Pipe**

The surge tank/pipe shall be designed considering the space available. The surge tank / pipe shall be of adequate size and capacity as per the requirement and approved design. It shall be provided with the isolation valve at inlet. The overflow arrangement shall be provided with the adequate arrangement for disposal of overflow water. The construction shall be as per the standard specifications of civil works.

6. PIPELINES, PIPEWORK AND FITTINGS

6.1 Applicable Codes

The following general codes and standards unless specified herein shall be referred to, or equivalent to the approval of the Engineer. The specific codes and standards have been given in the specific chapters.

6.1.1 Materials

IS:210	Specification for grey iron casting
IS:456	Code of practice for plain and reinforced concrete
IS:458	Specification for pre cast concrete pipes (with and without reinforcement)
IS:516	Method of test for strength of concrete
IS:638	Specification for sheet rubber jointing and rubber insertion jointing
IS:783	Code of practice for laying of concrete pipes
IS:816	Code of practice for use of metal arc welding for general construction in mild steel
IS:1367	Technical supply conditions for threaded steel fasteners
IS:1387	General requirements for the supply of metallurgical materials
IS:1500	Method for Brinell hardness test for metallic materials
IS:1536	Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage
IS:1537	Specification for vertically cast iron pressure pipes for water, gas and sewage
IS:1538	Specification for cast iron fittings for pressure pipes for water, gas and sewage
IS:1608	Metallic Material tensile testing at ambient temperature
IS:1916	Specification for steel cylinder pipes with concrete lining and coating
IS:3076	Specification for LDPE Pipes
IS:3597	Method of tests for concrete pipes
IS:3658	Code of practice for liquid penetrant flow detection
IS:4984	Specification for high density polyethylene pipes for water supply
IS:4985	Specification for PVC Pipes
IS:5382	Specification for rubber sealing rings for gas mains, water mains and sewers
IS:5504	Specification for spiral welded pipes

IS:6392	Specification for steel pipe flanges
IS:6587	Specification for spun hemp yarn
IS:7322	Specification for specials for steel cylinder reinforced concrete pipes
IS:8008	Specification for molded HDPE Fittings
IS8360	Specification for fabricated HDPE Fittings
IS:12709	Specification for GRP pipes
BS:5480	Specifications for GRP pipes and fittings

Additional Indian and International code of practices and specifications have been given below which shall be followed as much possible with the consent of the Employer's representative.

6.1.2 Code of Practice

IS:783	Code of practice for laying of concrete pipes
IS:2379	Color Code for Identification of Pipelines
IS:3114	Code of practice for laying pipes
IS:3764	**Excavation work - Code of Safety**
IS:4127	Code of practice for laying of glazed stoneware pipes
IS:5822	**Code of practice for laying of electrically welded steel pipes for water supply.**
IS:10221	**Code of Practice for coating and wrapping of underground MS pipelines**
IS:10990	**Technical drawings – Simplified representation of pipelines**
IS:11790	**Code of Practice for preparation of Butt welding ends for valves, flanges and fittings**

6.2 Materials for Pipelines

Each pipeline shall be constructed in a material compatible with the fluid conveyed through that pipeline, (i.e. the materials used in the pipes which are or can be in contact with the untreated or treated water, shall not contain any matter which could impart taste or odour or toxicity or otherwise be harmful to health or adversely affect the water conveyed). Pipes shall not be adversely affected by the fluid being conveyed through that pipe.

Pipework and valve materials of the suitable schedule for the following duties shall be as follows and equivalent to the approval of the Engineer.

The material of construction of pipes and fittings shall confirm to the following specifications:

Application/Location	Material	Remarks
Intake and outfall pipeline	HDPE	Refer Specification below
Raw seawater pumping	GRP	Refer Specification below
Brine disposal line	GRP	Refer Specification below
Sludge lines	GRP	Refer Specification below
Air Lines	SS-316L suitable for high temperature	Refer Specification below
RO piping (seawater/ brine) for high pressure lines	Super Duplex PERN>41	As per the application
Permeate line	GRP/HDPE	Refer Specification below
Service water	HDPE/ Ductile iron/MS with proper coating	As per approval of the Engineer
Chemical dosing Lines	Rubber lined carbon steel/ uPVC /GRP/HDPE	As per approval of the Engineer
Chlorine solution	HDPE Valves shall be globe type with forged steel bodies, monel spindles, stainless steel seats and PTFE gland packing or carbon steel	
Sewage and stormwater	HDPE/GRP/ RCC NP-3 pipes as per application	As per approval of the Engineer
Nut & Bolts	SS-316L	Refer Specification below
Fasteners	SS-316/ Monel 410/ K500	As per the application

6.3 Pipework

i) The term "pipework" means pipe of any description and includes associated flanges, dismantling joint adopters, couplings, jointing materials, fittings, supports, valves, traps and the like which are necessary to complete station pipework systems associated with pumping stations.

ii) The Contractor shall design, manufacture, supply, fabricate, and install the pipework in accordance with the Specification and to satisfy pipework function of Pump Station and other piping. The Contractor shall provide all the information given below clearly about the pipework. The Contractor's specification for the fabrication of pipework shall be submitted for the Employer's approval. The information provided shall be, when applicable, as listed below.

a) Purpose

b) Contents

c) Related documents

d) Definitions

e) Application standards

f) Drawings

g) Materials

h) Fabrication - general
   - tolerance
   - preparation
   - fit-up
   - threading
   - bends
   - welding
   - heat treatment
   - after fabrication treatment
   - inspection

i) Preparation and protection finishing of surfaces

j) Marking and color coding for identification and matching

k) Acceptable welder's qualification

iii) All pipes, fittings, bolts, nuts, jointing materials, pipe supports, thrust blocks and appurtenances for piping to be required for execution of the Works shall be manufactured and erected in accordance with the erection plans, specifications to be provided by the Contractor and approved by the Employer. All pipework and fittings shall be rated to the higher-pressure class in excess of the maximum pressure attained in service including any surge pressure. Minimum 2 mm corrosion allowance shall be considered. Where pipe material is specified as Mild steel, the pipe thickness shall be based on diameter and not be less than 12 mm. Buried pipes in addition to above, shall be designed to withstand external loading exerted by soil, water, and live loads as relevant. The external ground water shall be taken at ground level for design purposes.

iv) Underground pipelines must be shown the location by concrete pole that indicates its lay underground depth and its flow direction.

v) The pipe work installation shall be so arranged to offer ease of dismantling and removal of pumps or other major items of equipment. Stainless steel to Grade AISI 316 expansion bellows which can take radial and axial misalignment of minimum 1 percent of valve nominal size with tie rods shall be included in the suction and delivery pipe work of all pumps as well as on delivery header for easy dismantling, and provision shall be made for a flexible joint arrangement to building structures. All loose flanges shall be secured to fixed flanges by suitable tie-bolts.

vi) All necessary supports, saddles, slings, fixing bolts and foundation bolts shall be supplied to support the pipe work and its associated equipment in an approved manner. Valves, meters, strainers and other devices mounted in the pipe work shall be supported independently of the pipes to which they connect. All brackets or other forms of support, which can conveniently be so designed, shall be rigidly built up of steel by welding and coated by paint after wielding works.

vii) All pipework shall be adequately supported with purpose-made fittings. When passing through walls, pipework shall incorporate a puddle flange or other suitable sealing device.

viii) Flange adapters and unions shall be supplied and fitted in pipework runs, wherever necessary, to permit the simple disconnection of flanges, valves and equipment. The final outlet connection of the pipework shall match the connecting point of the transmission main.

ix) Flanged joints shall be made with minimum 3 mm thick full face, fabric reinforced rubber gaskets, pierced to take the bolts, and the face of all flanges shall be machined to give a true angle of 90^o to the centre line of the pipe or fittings. All necessary supports, saddles, slings, fixing bolts and foundation bolts shall be supplied to support the pipework and its associated equipment in an approved manner. Valves, meters and other devices mounted in the pipework shall be supported independently of the pipes to which they are connected.

x) Bolts for flange connection must be tightening adequate force in comply with international standards or approved by the Engineer.

xi) Facilities shall be provided for draining the pipe system and releasing air.

xii) The pipe work layout within all process pumping area shall have the approval of the pump manufacturer. Fluid velocities in suction pipework leading to pumps shall not exceed 1.5 m/s. Fluid velocities in delivery pipework leading from pumps shall not exceed 2.0 m/s except in case of HP piping for which up to 3 m/s may be permitted.

xiii) The whole of the jointing work and materials necessary to fix and connect the pipes, including adequate and efficient pipe support shall be included in the Contract. The Contractor shall be responsible for ensuring that the internal surface of all pipework is thoroughly cleaned before and during erection and before commissioning.

xiv) Cleaning shall include removal of all dirt, rust, scale and welding slag due to Site welding. Before dispatch from the manufacturer's works, the ends of the pipes, branch pipes, etc., shall be suitably capped and covered to prevent any accumulation of dirt or damage. This protection shall not be removed until immediately prior to connecting adjacent pipes, valves or pumps. All small-bore pipes shall be blown through with compressed air before connection is made to instruments and other equipment. No point of passage of pipes through floors or walls shall be used as a point of support, except with the approval of the Employer.

xv) Hydraulic shop test for pipes and fittings shall be conducted as per relevant code/standard requirement. After erection at Site, complete pipes and fittings shall be hydrostatically tested for a pressure of 1.5 times design pressure.

xvi) Flanges, if fabricated in segments shall be fully radiographed and stress relieved. If fabricated out of billets/bars by cold rolling, welded flanges shall be radiographed and normalized.

xvii) Protection for pipes laid underground shall be by coating and wrapping system giving a final coat thickness of 4.5 mm shall be employed. Such protection shall comprise 1.5 mm of coal tar primer application on a thoroughly cleaned surface, to be followed with fiber glass wraps set in coal tar enamel coats conforming to American Water Works Association Specification C/203/57 for a total thickness of 3 mm. Such lining shall meet a spark test to be approved with a holiday detector of 10000 Volts.

xviii) The Contractor shall indicate on his detailed drawings what thrust blocks are required to anchor pipework supplied by him. Particular care shall be taken to ensure that pipe work thrusts are, as far as possible, not transmitted to machinery or other associated apparatus.

xix) Puddle flanges shall be fitted to pipes where the structure through which they pass is required to take thrust resulting from the pipe. Puddle flanges shall also be fitted where a water barrier is required. All puddle flanges shall be clearly shown on the drawings and the resultant thrust clearly indicated. Puddle flanges shall only be fitted with the prior approval of the Engineer.

xx) Saddle type/ bracket type support wherever required shall be designed and supplied for the above ground pipe lines. The Employer's Representative shall duly approve all support design.

xxi) Air release valve shall be provided to release air when backwash by air is stopped. Type of valve shall be rubber pinch and shall be solenoid controlled.

xxii) All pipe lines shall be marked the flow direction, and print ink the name of liquid to be carried as well as name of the destination of facility.

xxiii) All pipelines shall be identified by stick-on 90-micron thick vinyl film labels showing the name of the material to be carried by the pipeline and an arrow indicating the direction of flow. Letters of titles shall be pre-spaced on carrier tape and the complete title protected by one-piece removable liners. Titles shall be at intervals not less than 8 m, but shall in any case be provided in every space through which the pipe passes. Locations of labels shall be subject to prior approval by the Employers Representative. Letter sizes shall be between 16 mm and 75 mm in height depending on the size of the pipe. Pipes smaller than 22 mm outside diameter shall be labelled by the use of tags instead of labels. Tags shall be made of brass no smaller than 65 m x 16 mm by 1.5 mm thick, with lettering etched and filled with black enamel. Titles shall also be provided on all equipment in locations and in sizes to be approved by the Employer's

Representative.

xxiv) The overhead portion of the pipeline inside building may be supported from the building structures, but in no case, support shall be taken from brick walls. The overhead pipe line wherein routed within the building shall have a clear head room of minimum 3.0 m from the operating floor.

6.4 GRP Pipes

The manufacturing, testing, supplying, joining and testing at work site of GRP pipes shall comply with all currently applicable statues, regulations, standards and codes. In particular, the following standards unless otherwise specified here in, shall be referred. In all cases, the latest revision of the codes shall be referred to. If requirements of this specification conflicts with the requirements of the codes and standards, this specification shall govern.

Design of GRP Pipes shall confirm to AWWA C-950/AWWA M45/ASTM 3517/ASTM 2310 or equivalent. The surfaces and edges of the pipes shall be well defined and true and shall have squareness of pipe ends as specified in IS: 14402 and ASTM D 3262.

The pressure class shall be established based on long term hydrostatic or pressure design basis in accordance with ASTM D 2992.

The resign and fiber glass to be used for pipe construction shall be suitable for handling fluid with deleterious effect for minimum 30 years and be in accordance with relevant clauses of IS 14402 and ASTM D 3262The materials sued shall be in accordance with the relevant clauses of IS : 6746, IS 14402, IS : 11320 and IS : 11551 and ASTM D 3262.

6.4.1 **Codes for GRP pipes**

(i) I.S. 14402: 1996

Glass-fibre reinforced plastics (GRP) pipes, joints and fittings for use for Sewerage, Industrial waste & Water (other than potable)- specification

(ii) I.S. 12709: 1994

Specification for glass fibre reinforced plastics (GRP) pipes for use for water supply and sewerage.

(iii) I.S. 6746: 1972

Unsaturated, polyester resin systems for low pressure fibre reinforced plastics,

(iv) I.S. 11273: 1985

Woven roving fabrics of 'E' glass fibre,

(v) I.S. 11320: 1985

Glass fibre roving for the reinforcement of polyester and of epoxide resin systems.

(vi) I.S. 11551: 1986

Wherever for certain specific requirements the information given in above mentioned IS codes is found to be inadequate, following international codes shall be referred to. However, in case of any discrepancy, decision of Employer / Employer's Representative shall be final and implemented by the Contractor.

(vii) ASTMD2412:

W Standard test method for determination of external loading characteristics of plastic pipe by parallel plate loading."

(viii) ASTM D 3262:

Standard specification for reinforced plastic mortar sewer pipe,

(ix) ASTM D 3517:

Standard specification for glass fibre reinforced thermosetting resin pressure Pipe,

(x) ASTM D 3618:

Test for chemical resistance of reinforced thermosetting resin pipe in a deflected Condition.

(xi) ASTM D 3839:

Standard practice for underground installation of flexible reinforced Thermosetting resin pipe and reinforced plastic mortar pipe.

(xii)ASTM D4161:

Standard specification for "Fibre glass" (glass-fibre - reinforced thermosetting resin) pipe joints using flexible elastomeric seals.

(xiii) ASTM D 477:

Standard specification for elastomeric seals (Gaskets) for joining plastic pipe.

(xiv) ASNI/AWWA C 950-88

AWWA standard for fiber glass pressure pipe.

(xv) IS 13916: 1994

Installation of GRP piping system - code of practice

(xvi) IS 5382: 1985

Rubber sealing rings for gas mains, water mains and sewers.

(xvii)American Society for Testing & Material (ASTM) 2563

Standard practice for clarifying visual defects in glass reinforced plastic laminated parts,

(xviii) ASTM D 5421

Standard specification for contact molded "Fiber glass" flanges,

(xvix) British Standard (BS) - 5480

Specification for Glass Fibre resin forced Plastic Pressure Pipes, Joints & Fittings.

6.4.2 **Manufacturing of GRP pipes**

The method of manufacturing of GRP pipes shall be such that the form and the dimensions of the finished pipes are accurate within the limits specified in the relevant clauses of Design Standard. The pipe shall be machine with continuous moving/filament winding. Hand woven pipes are not acceptable.

The basic structure wall composition shall consist of thermo-setting resin, glass fibre reinforcement and inorganic filler. The resin shall be Vinyl Ester. Thermoplastic or thermosetting liner and / or surface layer may be included. UV protection shall be applied on above ground pipe. No glass fibre reinforcement shall penetrate the interior surface of the pipe line. The pipe shall meet minimum longitudinal tensile strength and hoop tensile strength as per relevant clauses of design standards.

The GRP pipes and joints shall be systematically checked for any manufacturing defects by experienced supervisors so as to maintain a high standard of quality. Each pipe should have permanent ISI mark. Employer/ Employer's Representative shall at all reasonable times have free access to the place where the pipes and joints are manufactured for the purpose of examining and testing the pipes and joints and of witnessing the test and manufacturing.

a) Dimensions

Pipes shall be designated by nominal standard diameters. The nominal diameters, minimum wall thickness, length of barrel, joints etc. Shall be within the tolerance limits specified in IS: 14402, ASTM D 3262 and ASTM D 3517.

b) Workmanship and Finish

The inside surface of each pipe shall not have any visible defects such as bulges, dents, ridges foreign inclusion, cracks, crazing, pin holes and bubbles of 1.3 mm and above to the extent that it does not detrimentally affect the performance of the interior surface of the pipe wall.

Joint sealing surfaces shall be free of dents, gauges and other surface irregularities that will affect the integrity of the joints.

c) Structural Properties

The minimum initial ring stiffness for withstanding above load conditions with maximum 5% of long-term deflection shall be appropriately determined by manufacturer for actual execution.

d) Beam Strength

The pipe shall meet or exceed the minimum longitudinal tensile / compressive strength as per relevant clauses of IS: 14402, ASTM D 4262 and ASTM D 3517.

e) Hoop Tensile Strength

The pipes shall meet or exceed the minimum hoop tensile strength as per relevant clauses of IS: 14402, ASTM 3262 and ASTM D 3517.

f) Hydraulic Properties

Each length of pipe including specials shall withstand without leakage of cracking the internal hydrostatic proof pressures as per relevant clauses of IS: 14402, ASTMD 3517

g) Sampling and Inspection

In any consignment all the pipes of same class and size and manufactured under similar conditions of production shall be grouped together to constitute a lot. The conformity of a lot to the requirements of this specification shall be ascertained on the basis of tests on pipes selected from it. Unless otherwise agreed upon between the purchaser and the supplier one lot shall consist of maximum of 100 m of each pressure class, stiffness class and size of pipe produce.

Pipes shall be selected at random. In order to ensure randomness, all the pipes in the lot may be arranged in a serial order and starting from any pipe, every *'r'* the pipe be selected till the requisite number is obtained, 'r' being the integral part of N/n where 'N' is the lot size and 'n' is the sample size.

Each pipe shall be checked for dimensions, soundness, workmanship finish and deviation from straight.

The lot shall be declared as conforming to the requirements of this specification, if the sample pipe taken from the lot meets the requirements of all the tests, otherwise not.

6.4.3 **Testing of GRP pipes**

GRP pipes manufactured by the above process shall be subjected to the following tests.

All tests specified either in this specification or in the relevant clauses of Indian Standards or International Standards shall be performed by Supplier/ Contractor at his own cost and in presence of Employer / Employer's Representative if desired. For this, sufficient notice before testing of the pipes shall be given to Employer/ Employer's Representative. If the test is found unsatisfactory, Employer/ Employer's Representative may reject any or all pipes of that lot. The decision of Employer/ Employer's Representative shall be final and binding on Contractor and not subject to any arbitration or appeal.

(a) Testing of pipe at factory

After selecting pipe specimens randomly from the lot as per clause no. above they shall be tested at factory for following tests.

(b) Critical dimensions

All pipes will be measured for compliance with critical dimensions as specified in relevant clauses of IS 14407, ASTM D 3262 and ASTM D 3517 after allowing for the specified tolerances. The dimensions shall include diameter, wall thickness, sqareness and length. Pipes not in compliance will be rejected.

(c) Visual Acceptance

Generally, the pipe shall be free from all defects, including de-laminations, bubbles, pinholes, cracks, pits, blisters, foreign inclusions and resin-starved areas that due to their nature, degree or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in colour, capacity, density and other physical properties as per specification and standard BS 7152, AWWA, ASTM D2567, ASTM D3567 and ANSI B16.5.

Mechanical tests on spool shall be in accordance with ASTM- D.

(d) Tests for Specific Initial Ring Stiffness (SIRS)

Pipe ring samples shall be taken as discussed above from each diameter manufactured and tested for SIRS as per relevant clauses of IS 14407, ASTM D 2412 and ASTM D 3517. If a pipe sample from a lot fails to meet the required stiffness, a further two samples shall be tested from that lot. If they both pass, the lot will be accepted. If they fail Pipes will be tested on an individual basis and only pipes which pass will be accepted.

(e) Hydrostatic Soundness Test

The manufacturer shall hydrostatically test pipes by hydrostatic proof test in accordance with the relevant Clause of IS 14407 and ASTM D-3517. Pipes shall be tested for 1.5 times of maximum allowable working pressure (MAWP) that can be generated at any abnormal working condition foreseen by hydraulic surge study, etc. Piping shall be also tested against full vacuum. The procedure should be as follows:

Each length of pipe, shall be placed in a hydrostatic pressure test machine which seals the ends and exert no end loads. The pipe shall be filled with water, expelling all air and an internal water pressure shall be applied at a uniform rate not to exceed 300 Kpa/S until the test pressure of two times the pressure class is reached. This pressure shall be maintained for one minute. The pipe shall show no visual signs of weeping leakage or fracture of the structural wall. Integral bells, including reinforcement sleeves, if any, or affixed coupling shall be tested with the pipe. Any pipes failing to pass this test will be rejected. Rejected pipes may be repaired and retested, if they pass, they will then be accepted.

(f) Beam Strength Test

The manufacturer shall test the pipe for longitudinal tensile strength as per the relevant clauses in IS : 14407, ASTM D 2412, ASTM D 3262 and ASTM 3517. The sample size shall be selected as per clause above. If may sample should fail to meet the requisite value specified in the IS/ASTM codes, five (5) further samples should be taken and tested. If the results comply with requirement, all pipes will then be acceptable. However, if these five samples fail then all pipes from that lot will be rejected unless individually proven acceptable.

(g) Hoop Tensile Strength

The manufacturer shall test the pipe for hoop tensile strength as per relevant clauses in IS : 14407, ASTM D 3262, ASTM D 3517. The sample size shall be selected as per clause above. Every sample piece should meet or exceed the hoop tensile strength specified in IS : ASTM codes. If any sample fails to meet the requisite value five (5) further samples shall be taken and tested. IF the results comply with requirement, all pipes will then be acceptable. However, if these five samples fail then all pipes from that lot will be rejected unless individually proven acceptable. Rejected pipes will, however, be acceptable for use at a lower working pressure as per the criteria stated in the specification.

(h) Long Term Hydrostatic Strain Test

The pressure as classes as given in relevant clause shall be based on long term hydrostatic design pressure data obtained as per relevant clauses of IS: 14407, ASTM D 3262 and ASTM D 3517. For those products where no previous long term hydrostatic testing has been performed on similar products the full type testing shall be carried out to define design pressure classes based on extrapolated strengths at 50 years. When a hydrostatic design basis has already been established for a nominally similar pipe using the same manufacturing process, the manufacturer need only conduct the re-qualification test as described in the relevant clauses of IS : 12709.

(i) Test Certificate for Chemical resistance of GRP Pipes in a deflected Condition

The manufacturer / supplier / contractor shall produce a test certificate for chemical resistance of GRP pipes in a deflected condition that when installed within 5% deflection the pipes will last over 60 years under highly acidic and corrosive condition and stand guarantee for the same.

6.4.4 **Marking**

Both ends of each length of pipe and fitting shall be marked at least in letters not less than 12 mm in height and of bold type style in a colour and type that remains legible under normal handling and installation procedures. The marking shall include the following :

Internal diameter

Class of pipe (pressure and stiffness)

Date of manufacture

Name of manufacturer or his registered trade mark or both

Nominal thickness

All pipes and fittings shall have ISI mark.

6.4.5 **Handling**

The manufacturer / Supplier shall be responsible for safe delivery of pipes and fittings as per order place and as per the schedule. If the contractor for works is other than manufacturer / supplier, then M/s shall submit a complete manual of instruction/ guide / Procedure for handling of pipe before installation. Broadly following instructions/ procedures shall be followed.

Rubber ring gasket shall be shipped separately from the couplings and shall be stored in the shade in their original packaging and shall not be exposed to sunlight except during utilisation. The gaskets shall also be protected from exposure to greases and oils which are petroleum derivatives and from solvents and other deleterious substances.

Gasket lubricant shall be carefully stored to prevent damage to the container. Partially used buckets shall be prevented from contamination of the lubricant.

Unloading, lifting and lowering

Adequate control shall be ensured during unloading and lifting of pipes with guide ropes attached to pipes or packages. Spreader bars shall be sued when multiple locations are necessary. The pipes shall not be dropped to avoid impact or bump, particularly at pipe ends.

Non-utilised stack of pipes shall not be handled a single bundle. Non-utilised pipes shall be handled separately, one at a time. Pipes shall be handled or lifted with pliable straps, slings or ropes. Steel cables or ropes shall not be used for lifting and transportation of pipe. Ropes shall not pass through the section of pipe, end to end. If any time during handling or installation of pipe, any damage, such as gouge, crack or fracture occurs, the pipe shall be repaired or replaced as directed by Employer / Employer's Representative before installation.

6.4.6 **Jointing Pipes**

Pipe sections shall be jointed utilising double bell couplings and shall be assembled as indicated in the following paragraphs and as per the relevant clauses of ASTM D 3517, ASTM D 4161. The gasket used for jointing purpose shall be as per ASTM F447, specification for Elastomeric Seals (gasket) for joining plastic pipes.

(a) Clean Coupling

Double bell coupling grooves and rubber gasket ring shall be thoroughly cleaned to make sure no dirt or oil is present.

(b) Install Gaskets

The gasket shall be inserted into the grooves, leaving two to four uniform loops of rubber extending out of the groove. There should be a minimum of one loop for each 450 mm of gasket ring circumference.

(c) Lubricate Gaskets

Uniform pressure shall be applied to push each loop of the rubber gasket into the gasket groove. Then using a clean cloth, a thin film of lubricant shall be applied to the rubber gasket. Normal amount of lubricant consumed per joint shall be as follows

600 - 800 mm dia. -0.1 Kg

900 -1000 mm dia. -0.15 Kg

1100-1200 mm dia. - 0.20 Kg

1300-1400 mm dia. - 0.25 Kg

1500-1600 mm dia. - 0.30 Kg

1800 mm dia. - 0.35 Kg

(d) Clean and Lubricate Spigots

Pipe spigots shall be thoroughly cleaned to remove any dirt, grit, grease, etc. Using a clean cloth, a thin film of lubricant shall be applied to the spigots from the end of the pipe to the black positioning stripe.

(e) Fixing of Clamps

The first clamp is fixed anywhere on first pipe or left in position from previous joint. The second clamp is to be fixed on the pipe to be connected in the correct position relative to the alignment stripe on the spigot end so as also to act as a stopper. Clamp contact with the pipe shall be padded or otherwise protected to prevent damage to the pipe and have high friction resistance with the pipe surface. Care shall be taken in the alignment of the coupling.

(f) Pipe Placement

The pipe to be connected shall be placed on the bed with sufficient distance from the previously joined pipe to allow lowering the coupling into position.

(g) Join Coupling

Come along jacks shall be installed to connect the pipe clamps and two 10 cm x10 cm timbers or similar (large diameters may require a bulkhead) are placed between the pipe previously connected and the coupling. While these are held in position, the

new pipe shall be entered into the coupling until it rests against the second pipe clamp. Come-along jack might need protective plank in order not to rub against the pipe.

(h) Join Pipes

Come - along jacks shall be loosened and the timbers removed before retightening the jacks for entering the coupling onto the previously connected pipe. Correct position of the edge of the coupling to the alignment stripe home line shall be checked.

(i) Angular Deflection

Maximum angular deflection (turn) at each coupling joint shall not exceed the amounts given below. Also the pipes should be joined in straight alignment and thereafter deflected angularly if necessary.

(j) Layup Joints

The manufacturer / tenderer shall provide full details of the layup joints and polymer resin which will be used for connection of pipes to Chambers/manholes.

Joining pipes with different wall thickness when two pipes of same diameter but of different wall thickness are required to be joined at site, the contractor is required to execute the joint very precisely so as to have straight alignment of pipe inverts. Facilities shall be provided for draining the pipe system and releasing air.

The pipe work layout within all process pumping area shall have the approval of the pump manufacturer. Fluid velocities in suction pipework leading to pumps shall not exceed 1.5 m/s. Fluid velocities in delivery pipework leading from pumps shall not exceed 2.0 m/s.

The whole of the jointing work and materials necessary to fix and connect the pipes, including adequate and efficient pipe support shall be included in the Contract. The Contractor shall be responsible for ensuring that the internal surface of all pipework is thoroughly cleaned before and during erection and before commissioning.

Cleaning shall include removal of all dirt, rust, scale and welding slag due to Site welding. Before dispatch from the manufacturer's works, the ends of the pipes, branch pipes, etc., shall be suitably capped and covered to prevent any accumulation of dirt or damage. This protection shall not be removed until immediately prior to connecting adjacent pipes, valves or pumps. All small bore pipes shall be blown through with compressed air before connection is made to instruments and other equipment. No point of passage of pipes through floors or walls shall be used as a point of support, except with the approval of the Employer.

In the design of pipes above ground pipelines, the supports and guides for the pipe become important considerations because of thermal expansion. In addition to pressure resistance and life limitations, the effect of thermal expansion and contraction shall be considered while designing the pipe. Expansion joints shall be used whereas necessary to accommodate the changes in length associated with thermal expansion.

Hydraulic shop test for pipes and fittings shall be conducted as per relevant code/standard requirement. After erection at Site, complete pipes and fittings shall be hydrostatically tested for a pressure of 1.5 times design pressure.

Dimensions of all fittings should be approved by Employer's Representative. Each fitting shall be supplied with necessary coupling and flanges.

6.5 Super Duplex Piping and Fittings;

6.5.1 Manufacturing

The pipe shall be made by the seamless or an automatic welding process, with no addition of filler material in the welding process as per the ASTM A790 specification.

The pipe shall be pickled free from Scale. When bright annealing is used pickling is not necessary.

The pipes and joints shall be systematically checked for any manufacturing defects by experienced supervisors so as to maintain a high standard of quality. Employer/ Employer's Representative shall at all reasonable times have free access to the place where the pipes and joints are manufactured for the purpose of examining and testing the pipes and joints and of witnessing the test and manufacturing.

Care shall be taken that the resulting wall thickness does not become less than the minimum specified. If the wall thickness becomes less than the minimum specified, as per ANSI B36.19, the damaged portion should be cut out as cylinder and replaced by an undamaged piece of pipe at no extra cost to the Employer

6.5.2 General

This specification covers Seamless and straight seam welded Austenitic / ferritic steel pipe intended to use under corrosive service with particular emphasis on resistance to stress corrosion cracking.

The manufacturing, testing, supplying, joining and testing at work site of Super duplex pipes shall comply with all currently applicable statues, regulations, standards and codes. In particular, the following standards unless otherwise specified here in, shall be referred. In all cases, the latest revision of the codes shall be referred to. If requirements of this specification conflicts with the requirements of the codes and standards, this specification shall govern.

6.5.3 Applicable Codes

ASTM A 815	Standard specification for Wrought ferritic, ferritic / Austenitic, and Martensitic stainless-steel fittings
ASTM A 262	Practice for detecting Susceptibility to intergranular Attack in Austenitic stainless Steel
ASTM A 388/ A388 M	Practice for ultrasonic examination of heavy steel forgings
ASTM A 960/A 960M	Specification for common requirements for wrought steel piping fittings
ASTM A 763	Practice for detecting Susceptibility to intergranular Attack in Ferritic S Steel
ASTM A 234/ A 234M	Specification for piping fitting of wrought carbon steel and alloy for moderate and elevated temperatures
ASTM A 275/275M	Test method for magnetic particle examination of steel forgings
ASTM A 336/336M	Specification for steel forgings alloy for high press and high temperature parts
ASTM A 403/403A	Specification for Wrought austenitic stainless-steel piping fittings

ASTM A 479/A 479M	Specification for stainless and heat resistant bar and shapes for use in boilers and other pressure vessel
ASTM A 484/A 484M	Specification for general requirements for stainless steel and heat-resistant bars, billets and forgings
ASTM A 739	Specification for steel bars, Alloy, Hot-Wrought for elevated temperature for pressure containing parts, or both
ASTM A 751	Test methods practices, & terminology for Chem Analysis of steel products
MSS SP-43	Standard practice for light weight stainless butt-welding fittings
MSS SP-79	Socket welding reducer inserts
MSS SP-83	Steel pipe unions, Socket-Welding and threaded
MSS SP-95	Swage nipples and plugs
ASME B 16.9	Wrought Steel Butt-welding fittings
ASMEB 16.11	Forged Steel fittings, socket welding and threaded
ASME B 16.5	Dimensional Standard for steel pipe flanges and flanged fittings
ASMEB 16.10	Face-to-face and End-to-End Dimension of ferrous fittings
ASME Section IX- Welding Qualification	
SFA- 5.4	Specification for corrosion-resistance chromium and chromium-Nickel steel covered welding electrodes
SFA- 5.5	Specification for low-Alloy steel covered arc welding electrodes
SFA- 5.9	Specification for corrosion-resistance chromium and chromium-Nickel steel welding rods and electrodes

6.5.4 **Properties**

The material shall withstand under severe corrosive environment and pipe shall meet or exceed the minimum longitudinal tensile / compressive strength as per relevant clauses of ASTM A790 specification.

The material shall conform the chemical requirements as prescribed in ASTM A790 specification such that the PREN number should not be less than 41, The PREN number shall be calculated through the following formula:-

PREN = %Cr + 3.3 x %Mo + 16 x %N, Where Cr- Chromium, Mo- Molybdenum, N-Nitrogen

The steel shall conform to the tensile and hardness properties prescribed in ASTM A790 specification.

6.5.5 Dimension

Pipes shall be designated by nominal standard diameters. The nominal diameters, minimum wall thickness/schedule number, length of barrel, joints etc. Shall be within the tolerance limits specified in ANSI B36.19/ASTM A999.

6.5.6 Heat Treatment

Unless otherwise stated in order, all pipes shall be furnished in the heat treated condition as specified in ASTM A790 specification.

For seamless pipe, as an alternative to final heat treatment in a continuous furnace or batch type furnace, immediately following hot forming while the temperature of the pipe is not less than the specified minimum solution treatment temperature, pipes shall be individually quenched in water or rapidly cooled by other means.

6.5.7 Workmanship and Finish

The finished pipe shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thickness are not decrease to less than that permitted , in the permissible variation in wall thickness section of specification A999/A999M.

6.5.8 Testing

6.5.8.1 *Mechanical Testing*

One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension test shall be made on specimens of more than 100 pipes.

For a pipe heat treated in a batch type furnace, flattening test shall be made on 5% of the pipe from each heat-treated lot. For a welded pipe with a diameter equal to or exceeding NPS 10, a transverse guided face bend test of weld any be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of tests methods and definitions ASTM A 370.The ductility of the weld shall be acceptable when there is no evidence of cracks in the weld or between the base material after bending.

Brinell or Rockwell hardness tests shall be made on specimen from two pipes from each lot.

6.5.8.2 *Hydrostatic / Non-destructive Electric Test*

Each pipe shall be subjected to non-destructive electric or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in purchase order. The hydrostatic test shall be in accordance with specification ASTM B31.3.

Non-destructive electric test shall be in accordance with practice ASTM E213.

For eddy current test the maximum eddy-current coil frequency used shall be as per given value in ASTM A 790.

Pipes shall be tested for 1.5 times of maximum allowable working pressure (MAWP) that can be generated at any abnormal working condition foreseen by hydraulic surge study, etc. Piping shall be also tested against full vacuum.

6.5.8.3 *Repairing by Welding*

For welded pipes of size NPS 6 or larger with a specified wall thickness of 0.188 inch (4.8 mm) or more , weld repairs made with the addition of compatible filler metal may be made to the weld seam with the same procedure specified for plate defects in section on repair by welding of ASTM A999/A999M.

Weld repairs of the weld seam shall not exceed 20% of the seam length.

6.5.9 **Marking**

The following information shall be clearly marked on each pipe and special: Manufacturer's name or trademark

Material identification, either the ASTM or ASME grade designation Schedule number or nominal wall thickness in mm

Size - the nominal pipe size (NPS) identification number related to the end connections shall be used

Class of pipe (Grade or UNS number) and special with its serial number

6.5.10 **Jointing**

6.5.10.1 *Flanged Joint*

The flanges for pipes and specials shall be as per ANSI 16.5, with suitable rating applicable for the designed pressure. Flanges shall be provided at the end of pipes or specials where valves, blank flanges etc. have to be introduced or flanged joints for the pipes are specified. The flanges shall have necessary bolt holes drilled. It might be necessary for contractor to follow the instructions and specifications given by the valve manufacturer. All bolts, nuts and packing material required for flanged joints shall be provided by the Contractor. Bolts /studs, nuts and washer shall conform to ANSI B 18.2.1/ANSI B 18.2.2. Whereas metallic gasket with flexible graphite filled with carbon steel outer ring of required thickness shall conform to ASME B 16.20.

All the piping flanges and counter flanges & their drilling shall generally conform to ANSI B 16.5 of relevant pressure & temperature class.

6.5.10.2 *Welded Joint*

Where pipes or fittings are joined together by welding, following process can be used to weld Tungsten arc welding/ Plasma arc welding/Submerge arc Welding/ Metal Arc welding or any similar approved welding process as per approved Welding procedure specification (WPS) & Procedure Qualification Record (PQR). All welding work shall be carried out by qualified welders as per standard code ASME Section IX.

Pipes below 50 NB shall be plain end and the same shall be square groove welded, whereas pipes 50 NB & above shall be butt welded.

For Duplex Stainless-steel fittings and flanges shall be forged (wrought) or casting having the same schedule and equivalent material of construction having similar grade

Welded duplex/super duplex stainless steel piping need not be stress relieved except where specified in PQR. Such stress relieving may be done by uniformly heating welded area with nichrome/induction coil to 660± 15° C, holding the temperature for one hour for each 25 mm of wall thickness or fraction thereof, and then cooling at a rate not in excess of 315° C per hour in still air.

6.5.10.3 *Dismantling Joints*

The Contractor shall provide flexibility in the pipework at joints in the main structures and shall submit proposals for the approval of the Employer's Representative. Flexible joints shall also be provided for case of erection and future dismantling. Flexible couplings and flange adaptors shall be meeting with the requirements set forth by AWWA C 227 or similar approved pattern and be assembled in accordance with the manufacturer's instructions and protected.

Where steel and cast flanges are mated together the steel flange shall be machined over its full face, after welding to its respective pipe is completed.

Flexible joints shall be provided to facilitate installation and removal and or differential movement of plant. Where required, flexible joints shall be provided with tie bolts or other means to transfer longitudinal thrust along the pipework as a whole.

6.5.11 **Pipe Fittings**

The information under this clause covers the material specification, manufacturing, testing and other information for the piping fittings for the super duplex steel. Fittings shall be constructed of super duplex stainless steel material having PREN number equivalent to pipe system in which it is installed.

Fittings below 50 NB shall be forged fitting and butt weld ends, with relevant pressure rating not less than 3000#. The material shall be UNS S32750 as per ASTM A182/182M, Grade F 53 with PREN number not less than 41, the formula for calculating PREN number is given above in this document. The dimensional standard shall be as per ASMEB 16.11.

The ferritic steel may be made by the open hearth, electric furnace, or basic-oxygen process with separate degassing and refining optional. A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

After the hot working, forgings shall be cooled to a temperature below 538°C prior to heat treatment in accordance with the requirement as given in ASTM A182/182M.

The chemical properties/composition of the material shall be in accordance with ASTM A182/182M. Mechanical testing, cast analysis, product analysis, shall be governed by relevant ASTM specification.

Fittings 50 NB and above shall be wrought ferritic-austenitic stainless steel (seam welded) with butt-welded end. The material shall be UNS S32750 as per ASTM A815/ASTM 815M, Grade WP-W, with PREN number not less than 43, the formula for calculating PREN number is given above in this document. The dimensional standard shall be in accordance with ANSI B 16.9.

The fittings ordered as class WP-W shall meet the requirements of specification ASTM A 960/960M and shall have all welds made by fitting manufacturer of all pipe welds made with the filler material radio graphically examined throughout the entire length.

All welding shall be done prior to the heat treatment and all fittings shall be heat treated in accordance with the requirements specified in ASTM A815.

Fabricated elbows shall be made of a contiguous piece of pipe of the same material as the pipe system in which it is being installed. Cut grooves shall be integral on the elbow. No weld joints shall be accepted without X-ray inspection report of the weld. Groove must conform to coupling manufacturers published tolerances for cut grooves. No deviation shall be allowed. All Grooved Fittings must conform to internationally recognized quality assurance program or meet and conform to ASTM B31.3 severe cycle standards. Certificate of conformance shall be provided.

Factory trained representative shall visit job site to verify proper installation of fittings and couplings. Couplings manufacturer's installation instructions for couplings and fittings shall be followed.

6.5.12 **Pipe Flanges**

All flanges shall be forged and as per the ANSI B16.5, the material for flanges shall be UNS S32750 as per ASTM A182/A182M.

Flanges below 50 NB shall be Stub End + Lapped flange (FF) with pressure class rating of 600#, while Flanges 50 NB and above shall be RF with pressure Class 600#. Flanges shall be provided at the end of pipes or specials where valves, blank flanges etc. have to be introduced or flanged joints for the pipes are specified. The flanges shall have necessary bolt holes drilled. It might be necessary for contractor to follow the instructions and specifications given by the valve manufacturer.

All bolts, nuts and packing material required for flanged joints shall be provided by the Contractor. Bolts /studs, nuts and washer shall conform to ANSI B 18.2.1/ANSI B 18.2.2. Whereas metallic gasket with flexible graphite filled with carbon steel outer ring of required thickness shall conform to ASME B 16.20 as per table below.

Description	**Size**	**Dim. Std.**	**Material**	**Remark**
Pipe	Below 50 NB	B36.19	ASTM A790 UNS S32750	Seamless, PE

Pipe	50 NB and Above	B36.19	ASTM A790 UNS S32750	Seamless/Straight seam welded, BW end
Flange	Below 50 NB	ANSI B 16.5	ASTM A182 GRF53, UNS S32750	600#, Stub End + lapped flange (FF)
Flange	50 NB and Above	ANSI B 16.5	ASTM A182 GRF53, UNS S32750	600#, RF
Elbow 90	Below 50 NB	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	1.5DBW
Elbow 90	50 NB and Above	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	1.5D.BW
Tee	Below 50 NB	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	BW
Tee	50 NB and Above	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	BW
Reducer	Below 50 NB	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	BW
Reducer	50 NB and Above	ANSI B 16.9	ASTM A815 UNS S32750 WP-W	BW
Weldolet-Branch Butt Weld	Below 50 NB	MSS SP-97	ASTM A815 UNS S32750	Seamless
Gasket		B 16.20	3mm THK, spiral wound, SS 316, flexible graphite filled with carbon steel outer ring,	To suit Class 600#
Bolt / Stud , Nut& Washer		ANSI B 18.2.1/ANSI B 18.2.2	STUD: A193 GR.B88. NUT: A194 GR.8	

6.6 HDPE Piping

6.6.1 **Applicable Codes**

Polyethylene pipes shall comply with below mentioned Indian Standards /BS 6437.

The following Indian Standards /BS 6437, unless otherwise specified herein, shall be referred. In all cases the latest revision of the Codes shall be referred to. If requirements of this specifications conflict with the requirements of the standards /Codes, this specification shall govern. The welding method shall be adapted to international standard and contractor shall obtain the approval of the Engineer before proceeding with such works.

Code No.	Title/ Specification
ISO 4427E, EN12201	High Density polyethylene pipes
IS:2530	Methods of test for polyethylene moulding materials and polyethylene compounds
IS 4984 Amendment No. 21995	High Density polyethylene pipes for Water Supply
IS 5382	Rubber sealing rings for gas mains, water mains and sewers
IS:7328	High density polyethylene materials for moulding and extrusion
IS 7634	Laying & jointing of polyethylene (PE) pipes
IS 2530	Methods of test for polyethylene moulding materials and polyethylene compounds
IS 4905	Methods for random sampling
IS 9845	Methods of analysis for the determination of specific and / or overall migration of constituents of plastics material and articles intended to come into contact with foodstuffs.
IS 10141	Positive list of constituents of polyethylene in contact with food stuffs, Pharmaceuticals and drinking water.

The High-Density Polyethylene (HDPE) Pipe shall be made from base polymer and shall conform to the requirements as specified in ISO4427. The base polymer shall be a single grade of polyethylene. All raw material used shall be approved and certified Pipe Grade material for the transportation of potable water.

The Contractor shall provide the certified information (as per BIS) about the properties of PE-100 material as stated in the document for manufacturing the pipes for this project. Density, flexural strength, compressive strength, modulus of elasticity, short term and long term yield value, allowable circumferential stress in pipes intended for 40-50 years of service at normal temperature, volume resistivity, thermal conductivity, specific heat, linear coefficient of expansion, ignition by flame, burning rate, maximum operating temperature (under pressure) and any other properties which may affect the serviceability of pipe at project site. The Contractor shall submit original copy of the pipe manufacturer's sworn certificate of inspection and testing of all pipes and fittings used on the job. All pipes and fittings shall be subject to inspection and approval by the Engineer/ Employer's representative before and after delivery at the project site. Any pipe or fittings found to be unsatisfactory or otherwise damaged shall not be approved for use.

No additives that may contribute to toxic hazard, impair the fabrication of properties and chemical and physical properties in particular to long term mechanical and strength is allowed.

The colour of the pipes shall be black with blue stripes. Each pipe shall contain minimum three equi-spaced longitudinal stripes of width 3 mm (Min) in blue colour. These stripes shall be more than 0.2 mm in depth. The material of the stripes shall be of the same type of resin, as used in the base compound for the pipe.

All HDPE pipes shall conform to IS: 4984-1995 (with amendment) high density polyethylene pipes (HDPE) for potable water supplies (Fourth Revision) or ISO 4427-1996 with nominal outside diameters. The pressure rating of the pipes shall be governed by the design. The raw material of pipes shall conform to ISO 4437. The produced pipes shall pass the internal pressure test (acceptance test) using test method per EN 921.

The flanges system will follow systematically these requirements:

Nominal Pressure: 10 bars

Flange norms: ISO PN10, EN 1092-2 and ISO 7005-2.

The rubber gasket will follow these requirements:

Material: nitrile rubber

Thickness: min 4mm

For PN10 flanges

The bolts and nuts shall be Electro-galvanized steel;

Flanges will be used to fit together elements of different materials such as valves (in cast iron or ductile iron) with HDPE pipes through the use of a flange adaptor.

6.6.2 **Appearance**

The internal and external surfaces of pipes must smooth, clean and free from scoring, cavities and other surface defects which may affect pipe performance. The ends of pipe shall cut cleanly and square to the axis of the pipe. Appearance shall be checked at the point of manufacture.

Each straight length of pipe shall be clearly marked in indelible ink/paint on either end and for coil at both ends or hot embossed on white base every meter throughout the length of pipe/coil with the following information:

a) Manufacture's name and/or Trade-mark,

b) Designation of pipe

c) Lot No./Batch No.

d) BIS certification marking on each pipe/Equivalent in case of Import.

Ovality shall be measured at the manufactures end as the difference between the maximum outside diameter and minimum out-side diameter measured at the same cross section of the pipe, at 300mm away from the cut end. For pipes to be coiled, the ovality shall be measured prior to coiling For coiled pipes, however, re-rounding of pipe shall be carried out prior to the measurement of ovality.

6.6.3 **Pipe Fittings:**

Pipe fittings shall be laid so as to form a close concentric joint with the adjoining pipe to avoid sudden offsets of the flow line. Pipe sections shall be joined together in accordance with the manufacturer's recommendations.

6.6.4 **Butt Fusion Joining**

Plain end pipe and fittings shall be made using butt fusion. The butt fusion procedures shall be in accordance with the manufacturer and the relevant codes. The fusion equipment operator shall receive training using the recommended procedure. The Contractor shall be responsible to verify that the fusion equipment is in good operating condition and that the operator has been trained within the past twelve months. The fusion equipment shall be equipped with a Data logger. Records of the welds (heater temperature, fusion pressure, and a graph of the fusion cycle) shall be maintained for five (5) years. Fusion beads shall not be removed.

Butt fusion fittings shall have a manufacturing standard of ASTM D 3261. Molded & fabricated fittings shall have a pressure rating equal to the pipe unless otherwise specified in the plans.

Flanges adapters shall be attached to pipe and fittings using butt fusion. The flanges adapters shall be aligned and centered relative to the pipe. Flange adapters should be square with the valve or other flange before tightening of bolts. Bolts should not be used to draw flanges into alignment. Bolt threads shall be lubricated, and flat washers shall be used under flange nuts. Bolts shall be tightened using a "star tightening pattern". Twenty-four hours after first tightening the flange bolts, they must be re-tightened using the same "star tightening pattern used above. The final tightening torque shall be as indicated by the manufacturer.

Heat Fusion Training. The supplier of the pipe and fittings shall provide a person certified by the pipe manufacturer and the fusion equipment manufacturer to train contractor fusion equipment operators and inspectors representing the Owner.

Heater Surface Temperature: Minimum 400 °F - Maximum 450 °F

Heating tool surfaces must be to temperature before you begin. All points on both heating tool surfaces where the heating tool surfaces will contact the pipe or fitting ends must be within the prescribed minimum and maximum temperatures and the maximum temperature difference between any two points on the heating tool fusion surfaces must not exceed 20 °F for equipment for pipe smaller than 18" diameter, or 35 °F for larger equipment. It is a good practice to set the heater plate to 425 °F.

which can help keep normal fluctuations between 400 ^{o}F and 450 ^{o}F. Heating tool surfaces must be clean.

Interfacial pressure: Minimum 60 psi - Maximum 90 psi

Interfacial pressure is used to calculate a fusion joining gauge pressure value for hydraulic butt fusion machines or manual machines equipped with force reading capability. The interfacial pressure is constant for all pipe sizes and all butt fusion machines. However, fusion joining gauge pressure settings are calculated for each butt fusion machine, which is dependent upon the outside diameter (OD) and dimension ratio (DR) and the piston area of the fusion machine.

For hydraulic machines, the interfacial pressure, the fusion surface area, the machine's effective piston area and frictional resistance, and if necessary, the pressure needed to overcome external drag resistance, are used to calculate hydraulic fusion joining pressure gauge settings as per pipe manufacture.

The equipment manufacturer's instructions are used to calculate this value. The proper amount of force should be verified by visual inspection of the joint.

NOTE: The interfacial pressure and the hydraulic gauge pressure are not the same.

For manual machines without force reading capability, the correct fusion joining force is the force required to roll the melt beads over until they contact the pipe surface as required by the joining procedure.

Secure

Clean the inside and outside of the pipe or fitting (components) ends by wiping with a clean, dry, lint- free cloth or paper towel. Remove all foreign matter. Align the components in the machine, place them in the clamps, and then close the clamps. Do not force pipes into alignment against open fusion clamps. Component ends should protrude past the clamps enough so that facing will be complete. Bring the ends together and check high-low alignment. Adjust alignment as necessary by tightening the high side down.

Face

Place the facing tool between the component ends, and face them to establish smooth, clean, parallel mating surfaces. Complete facing produces continuous circumferential shavings from both ends. Face until there is minimal distance between the fixed and moveable clamps. If the machine is equipped with facing stops, face down to the stops. Stop the facer before moving the pipe ends away from the facer. Remove the facing tool, and clear all shavings and pipe chips from the component ends. Do not touch the component ends with your hands after facing.

Align

Bring the component ends together, check alignment and check for slippage against fusion pressure. Look for complete contact all around both ends with no detectable gaps and ODs in high-low alignment. If necessary, adjust the high side by tightening the high side clamp. Do not loosen the low side clamp because components may slip during fusion. Re-face if high-low alignment is adjusted.

Melt

Verify that the contact surface of the heating tool is maintaining the correct temperature. Place the heating tool between the component ends, and move the ends against the heating tool. Bring the component ends together under pressure to ensure full contact. The initial contact pressure should be held very briefly and released without breaking contact. Pressure should be reduced when evidence of melt appears on the circumference of the pipe. Hold the ends against the heating tool without force (drag force may be necessary to ensure contact). Beads of melted PE will form against the heating tool at the component ends. When the proper melt bead size is formed, quickly separate the ends and remove the heating tool. The proper bead size is dependent upon the size of the component. During heating, the melt bead will expand out flush to the heating tool surface, or may curl slightly away from the surface. If the melt bead curls significantly away from the heating tool surface, unacceptable pressure during heating may have occurred.

Join

Immediately after the heating tool is removed, quickly inspect the melted ends, which should be flat, smooth and completely melted. If the melt surfaces are acceptable, immediately and in a continuous motion, bring the ends together and apply the correct joining force (or fusion pressure). The correct fusion pressure will form a double bead that is rolled over and contacts the pipe surface. The surface on both ends. A concave melt surface is unacceptable; it indicates pressure during heating. Do not continue. Allow the component ends to cool and start over with Step 1 above again.

Hold

Maintain fusion gauge pressure until the joint is cool. The joint is cool enough for gentle handling when the double bead is cool to the touch. Cool for a minimum of 11 minutes per inch of pipe wall. Do not try to decrease the cooling time by applying water, ice, wet cloths or the like. Avoid pulling, installation, pressure testing and rough handling for at least an additional 30 minutes. For ambient temperatures above 100°F, longer cooling times may be required.

Inspection

On both sides, the double bead should be rolled over to the surface, and be uniformly rounded and consistent in size all around the joint.

The gap between the two single beads must not be below the fusion surface throughout the entire circumference of the butt joint.

The displacement between the fused ends must not exceed 10% of the pipe/fitting minimum wall thickness.

6.6.5 Electrofusion Couplings.

Polyethylene pipe and fittings may be joined using approved electrofusion couplings. Electrofusion Fittings shall have a manufacturing standard of ASTM F 1055. Fittings shall have a pressure rating equal to the pipe unless otherwise specified on the plans. All electrofusion fittings shall be suitable for use as pressure conduits, and per AWWA C906, have nominal burst values of three and one-half times the Working Pressure Rating (WPR) of the fitting.

6.6.6 Pipe Manufacturer's Quality Control.

The pipe manufacturer shall have an ongoing Quality Control program for incoming and outgoing materials. High-density polyethylene (HDPE) resins for manufacturing of pipe shall be checked for density, melt flow rate, and contamination. The manufacturer of the HDPE resin shall certify the Cell Classification as per his format. These incoming resins shall be approved by plant Quality Control before being converted to pipe. Pipe shall be checked for outside diameter, wall thickness, length, roundness, and surface finish on the inside and outside and end cut. Testing Pressure testing shall be conducted in accordance with ASTM standard.

6.6.7 Transport and Handling

Vehicles for transporting HDPE pipes should have a clean flat bed, free from nails and other projections which might cause damage. Each pipe should be supported along its length but, where this is not possible; timber supports of at least 75mm bearing width and placed at most 60 cm apart should be used. The above recommendations may not apply when rigid bundles of pipes are being transported. In that case the overall height of the bundles should not exceed 2.5 m. Side supports should not be less than 1.5 m apart; they should be flat and have no sharp or rough edges. When loading pipes with integral sockets, the sockets should be placed at alternate ends of the vehicle in such a way that they do not make contact with the neighbouring pipes. When transporting a mixed load of pipes, it is important that the larger, generally thicker-walled, and thus heavier, pipes are placed at the bottom. Pipes should not be allowed to overhang the vehicle.

6.6.7.1 *Pipe and Large Fitting Handling*

HDPE pipes are light in weight, they are therefore easy to handle. With reasonable care, damage to the pipes can be easily avoided. Pipes should not be dragged along the ground nor should they be lowered on skids. Whenever mechanical handling techniques are used, all equipment coming into contact with the pipes should be made of a soft material. A nylon fabric choker sling capable of safely handling the weight of the pipe or fitting, shall be used to lift, place and move pipe and fittings or For example, textile slings and Hessian ropes may be used and it should be ensured that all metal hooks are covered.

While unloading pipes from vehicles, do not drop them on the ground. Pipes should always be carefully lowered onto the ground or stacked where they are to be stored. Whenever pipes have been transported one inside another, the inner pipes should always be removed first and stacked separately.

6.6.7.2 *Storage*

Generally, similar requirements apply to storage of HDPE and uPVC pipes.

Pipes may be stored in loose stacks up to a maximum height to 2 m.

When pipes are stored outside in climates having high ambient temperatures (greater than 23 °C), the following is recommended:

a) The height of the stacks should not exceed 1 m;

b) all stacks should be shielded from continuous and direct sunlight and shall be arranged to allow the free passage of air around the pipes; specials & fittings should always be stored in boxes or sacks manufactured so as to permit the free passage of air.

c) When pipes are stacked in the form of rigid bundles, a maximum of three bundles having a height of 1 m each should be stacked on top of each other.

6.7 CPVC Pipe:

This specification outlines minimum manufacturing requirements for Chlorinated Polyvinyl Chloride (CPVC). This pipe is intended for use in applications where the fluid conveyed does not exceed 140°F. This pipe meets and or exceeds the industry standards and requirements as set forth by the American Society for Testing and Materials (ASTM), ISO and the National Sanitation Foundation (NSF International).

The material used in the manufacture of the pipe shall be a rigid chlorinated polyvinyl chloride (CPVC) compound, Type IV Grade I, with a Cell Classification of 23447 as defined in ASTM D1784. This compound shall be light gray in color, and shall be approved by NSF for use with potable water. The pipe shall be manufactured in strict compliance to ASTM F441, consistently meeting the Quality Assurance test requirements of this standard with regard to material, workmanship, burst pressure, flattening, and extrusion quality. The chlorine content in pipe at a time shall not be less than 66.5%.

The pipes shall be as per IS 15778, latest edition for water supply.

Solvent-cemented joints should be utilized when working at or near maximum temperatures. The use of PVC for threaded connections at temperatures above 110°F; is not recommended, above the same flanged joints, unions, or roll grooved couplings where disassembly is necessary at elevated temperatures shall be used.

Thread only Schedule 80 or heavier walls. Threading requires a 50% reduction in pressure rating stated for plain end pipe @73°F. Threading of Schedule 40 PVC pipe is not a recommended practice due to insufficient wall thickness.

Chemical resistance data should be referenced for proper material selection and possible de-rating when working with fluids other than water.

6.8 Hydrotesting

6.8.1 Hydro-testing of HDPE/CPVC Pipes

Hydro pressure testing shall be done on the laid pipe length for a minimum pressure of 1.5 times the designed working pressure (but not less than 6 bar) for retaining period of 4 hours, and as mentioned in IS 4984 -1995 including its latest amendments. A report shall be prepared by the Contractor and submitted to the Employer's representative to provide the details of the pipe laid, source of water to be used for hydrotesting with the proposal of hydrotesting on a given date. The acceptance criteria for hydrostatic test are no permanent deformation of any part of the pipeline fitting or equipment and there shall not be any leakage through any of the joints.

All the necessary consumables, equipment, tools & tackles required for the testing & inspection has to be arranged by the Contractor

Hydro pressure testing has to be done for all the valves as per IS 13095 -1991 including its latest, at the manufacturer's end and a report has to be submitted to the Employer's Representative

6.8.2 Hydrotesting of Valves and Other Fittings

Suitable section shall be chosen for such testing in consultation with Employer's Representative from time to time during progress of the work and satisfactorily tested. All testing apparatus, gauges, connections, etc. and water required for testing shall be arranged by the contractor at his cost. The water for testing has to be arrange by the Contractor

Satisfactory hydraulic test shall be recorded when the section under test shall withstand the pressure for about 15 minutes without operating the test pump. The test pressure being maintained at the specified figures during that 15 minutes interval.

The field test pressure to be imposed should be not less than the maximum of following.

a) 1.5 times the maximum sustained operating pressure.

b) 1.5 times the maximum static pressure in the pipe line

During testing if any joints are found leaking they shall be repaired and / or reinstalled by the Contractor at his cost till the test is found satisfactory. Similarly, any pipes collars, specials, show hair cracks, leaks etc. during testing the contractor shall replace them with sound pipes and specials etc. free of cost. The hydraulic test shall be carried out after noticing the Employer's Representative.

Water tightness of the valve joints shall be tested in the same manner as described for mains. These tests may be carried out along with the tests of the pipe mains and separate tests are not essential.

6.8.3 Testing of Pipes & Specials, Pipeline and Joints

All tests specified in this specification, relevant Indian Standards as per codes followed and manufacturer's instruction manual, applicable for HDPE and uPVC pipes respectively and specials, shall be carried out by the contractor at his own cost.

Before commencing the factory testing of pipes and specials and fittings, notice period of 15 days shall be given to the Employer's Representative.

Certificate from the manufacture, certifying compliance to all tests for all lots and diameter of pipe needs to be submitted before transporting the pipe to site.

The under given test shall be carried out for HDPE pipes:

(i) Resistance to internal pressure - Test method

The internal pressure test is standardized in ISO 1167. The test specifies a method for determination of the resistance to constant internal pressure at constant temperature.

(ii)The Pipe notch test

The Pipe notch test is standardized in ISO 13479 as "Polyolefin pipes for the conveyance of fluids - Determination of resistance to crack propagation - Test method for slow crack growth on notched pipes (notch test)". The test simulates slow crack growth and record time to failure on notched pipes.

(iii) The Small-scale steady-state test

The small-scale steady-state test (S4 test) is standardized in ISO 13477 "Thermoplastics pipes for the conveyance of fluids - Determination of resistance to rapid crack propagation (RCP)." The test simulates the phenomenon of RCP in plastic pipes and measure the determination of arrest or propagation of an initiated crack. In pipelines RCP, caused by a brittle crack, could undergo the length of several hundred meters almost at the sound of speed.

Flanges, if fabricated in segments shall be fully radiographed and stress relieved. If fabricated out of billets/bars by cold rolling, welded flanges shall be radiographed and normalized.

Protection for pipes laid underground shall be by coating and wrapping system giving a final coat thickness of 4.5 mm shall be employed. Such protection shall comprise 1.5 mm of coal tar primer application on a thoroughly cleaned surface, to be followed with fiber glass wraps set in coal tar enamel coats conforming to American Water Works Association specification C/203/57 for a total thickness of 3 mm. Such lining shall meet a spark test to be approved with a holiday detector of 10000 Volts.

The Contractor shall indicate on his detailed drawings what thrust blocks are required to anchor pipework supplied by him. Particular care shall be taken to ensure that pipe work thrusts are, as far as possible, not transmitted to machinery or other associated apparatus.

Puddle flanges shall be fitted to pipes where the structure through which they pass is required to take thrust resulting from the pipe. Puddle flanges shall also be fitted where a water barrier is required. All puddle flanges shall be clearly shown on the drawings and the resultant thrust clearly indicated. Puddle flanges shall only be fitted with the prior approval of the Employer.

6.9 Ductile Iron Pipes and Fittings

6.9.1 Pipes and Fittings

6.9.1.1 *General*

Ductile iron pressure pipes and fittings (Class K9) shall comply with IS:8329 and IS:9523. All fittings shall be socketed unless specified otherwise.

6.9.1.2 *Materials*

The materials used in the manufacture pipes and fittings shall comply with IS:8329 and IS:9523.

6.9.1.3 *Tests*

Tests on pipes and fittings shall be carried out in accordance with IS:8329 and IS:9523. The test method shall be submitted for approval of the Engineer.

The Engineer shall be permitted free access to the place of manufacture for the purpose of examining, inspection and witnessing the testing of pipes and fittings

6.9.2 Joints

6.9.2.1 *Spigot and Socket Joints*

These shall have sockets which are integral with the pipe and incorporate an elastomeric rubber ring gasket conforming to IS:12820.

6.9.2.2 *Flanged Joints*

These shall comply with dimensions and drilling details shall be to BS EN 1092-2. All flanged joints of dissimilar material such as between steel and ductile iron pipe work shall be electrically isolated joints. These shall have isolation gaskets between the flanges, isolation sleeves around all bolts and isolation washers under all bolt heads and nuts. All materials shall be supplied by a specialist manufacturer and be to the approval of the Engineer.

6.9.3 Linings

Ductile iron pipes and fittings shall have a cement mortar lining, in accordance with IS:11906 or ISO 4179. Pipe linings shall be inspected on site and any damage or defective areas made good to the satisfaction of the Engineer. The Contractor may use specialist mortars, mortar additives or curing agents only with the approval of the Engineer.

Certain sections are amplified as follows:

No additives shall be used without the written approval of the Engineer, and shall be used strictly in accordance with the manufacturer's recommendations.

The minimum thickness of the lining at one point shall not be less than that specified in IS:8329.

6.9.4 Coating

6.9.4.1 *General*

Ductile iron pipes and fittings shall be zinc coated with bitumen over coating, all in accordance with the following Specifications. Buried pipes and fittings shall also have a site or factory applied polythene sleeving. Pipe coatings shall be inspected on site and any damage or defective areas made good to the satisfaction of the Engineer.

6.9.4.2 *Zinc Coating*

Zinc coating shall comply with ISO 8179 and shall be applied as a spray coating. The mass of sprayed metal shall not be less than 130 g/m^2 as described in Clause 5.2 of ISO 8179.

6.9.4.3 *Bitumen Coating*

Bitumen coating shall be of normal thickness 0.07 mm unless otherwise specified. It shall be a cold applied compound complying with the requirements of BS 3416 Type II, suitable for tropical climates, factory applied in accordance with the manufacturer's instructions.

Damaged areas of coating shall be repainted on site after removing any remaining loose coating and wire brushing any rusted areas of pipe.

6.9.4.4 *Polythene Sleeving*

Where polythene sleeving is specified (generally for all buried DI pipes) to be applied in addition to bitumen coating it shall comply with ISO 8180. Site applied sleeving shall be stored under cover, out of direct sunlight, and its exposure to sunlight shall be kept to a minimum. Pipes having a factory applied sleeving must be stored in the same conditions.

6.10 Reinforced Cement Concrete Pipes

6.10.1 Design

Design of RCC pipes including reinforcement details and the ends of pipes shall be in accordance with the relevant clauses of IS:458.

6.10.2 Manufacturing

6.10.2.1 *General*

The method of manufacture shall be such that the form and the dimensions of the finished pipes are accurate within the limits specified in relevant clause of IS:458. The surfaces and edges of the pipes shall be well defined and true, and their ends shall be square with the longitudinal axis. The ends of the pipes shall be further reinforced by an extra ring of reinforcement to avoid breakage during transportation.

The reinforced concrete pipes and collars/rubber rings shall be systematically checked for any manufacturing defects by experienced supervisors so as to maintain a high standard of quality.

The Engineer shall at all reasonable times have free access to the place where the pipes and collars/rubber rings are manufactured for the purpose of examining and testing the pipes and collars/rubber rings and of witnessing the manufacturing and testing.

All tests specified either in this Employer's/Engineer's Requirements or in the relevant Indian standards shall be performed by the supplier/contractor at his own cost and in presence of the Engineer. For this, sufficient notice before testing of the pipes and fittings shall be given to the Engineer.

If the test is found unsatisfactory, the Engineer may reject any or all pipes of that lot. The decision of the Engineer in this matter shall be final and binding on Contractor and not subject to any arbitration or appeal.

6.10.2.2 *Materials*

For all materials Factory's test results, and written guarantee document with necessary analysis data shall be submitted to obtain the approval of the Engineer before carrying to sites.

6.10.2.3 *Cement*

Cement used for the manufacture of RCC pipes and collars shall conform to relevant IS codes. The use of pozzolana as an admixture to Portland cement shall not be permitted.

6.10.2.4 *Aggregates*

Aggregates used for the manufacture of RCC pipes and collars shall conform to IS:383. The maximum size of aggregate should not exceed one third the thickness of the pipe or 20mm, whichever is smaller.

6.10.2.5 *Mixing and Curing Water*

Water shall be clean, colourless and free from objectionable quantities of organic matter, alkali, acid, salts, or other impurities that might reduce the strength, durability or other desirable qualities of concrete and mortar. Contractor shall submit water quality report before using it.

6.10.2.6 *Reinforcement*

Reinforcement used for the manufacture of the RCC pipes and collars shall be mild steel Grade I or medium tensile steel bars conforming to IS:432 (Part-1) or hard-drawn steel wire conforming to IS:432 (part-2). Reinforcement cages for pipes and collars shall be as per relevant requirement of IS:458.

6.10.2.7 *Concrete*

Concrete used for the manufacture of RCC pipes and collars shall conform to IS:456. The minimum cement content and minimum compressive strength of concrete shall be as per relevant requirements of IS:458. Compressive strength tests shall be conducted on 15 cm cubes in accordance with the relevant requirements of IS:456 and IS:516.

6.10.2.8 *Curing*

Pipes manufactured in compliance with IS:458 shall be either water cured or steam cured in accordance with the relevant requirements of IS:458.

6.10.2.9 *Dimensions*

The internal diameter, wall thickness and length of barrel and collar of pipes, reinforcement (longitudinal and spiral), type of ends and minimum clear cover to reinforcement and strength test requirements shall be as per the relevant clauses / tables of IS:458 for different classes of pipes.

The tolerances regarding overall length, internal diameter of pipes or sockets and barrel wall thickness shall be as per relevant clause of IS:458.

6.10.2.10 *Workmanship and Finish*

Pipes shall be straight and free from cracks. The ends of the pipes shall be square with their longitudinal axis so that when placed in a straight line in the trench no opening between ends in contact shall exceed 3 mm in pipes up to 600mm diameter (inclusive), and 6 mm in pipes larger than 600 mm diameter.

The outside and inside surfaces of the pipes shall be smooth, dense and hard, and shall not be coated with cement wash or other preparation unless otherwise agreed to between the Engineer and the manufacturer or supplier.

The pipes shall be free from defects resulting from imperfect grading of the aggregate, mixing or moulding. The pipes shall be free from local dents or bulges greater than 3 mm in depth and extending over a length in any direction greater than twice the thickness of barrel.

The deviation from straight in any pipe throughout its effective length, tested by means of rigid straight edge parallel to the longitudinal axis of the pipe shall not exceed, for all diameters 3 mm for every meter run.

6.10.2.11 *Testing*

All pipes for testing purposes shall be selected at random from the stock of the manufacturer and shall be such as would not otherwise be rejected under the criteria of tolerances as mentioned in IS:458. Engineer reserve the right to attend all testing.

During manufacture, tests on concrete shall be carried out as per IS:456. The manufacturer shall supply, when required to do so by the Engineer, the results of compressive tests of concrete cubes and split tensile tests of concrete cylinders made from the concrete used for the pipes. The manufacturer shall supply cylinders or cubes for test purposes required by the Engineer and such cylinders or cubes shall withstand the tests prescribed as per IS:458. Every pressure pipe shall be tested by the manufacturer for the hydrostatic test pressure. For non-pressure pipes, 2 percent of the pipes shall be tested for hydrostatic test pressure.

The specimen of pipes for the following tests shall be selected in accordance with relevant clause of IS:458 and tests in accordance with the methods described in IS:3597.

a) Hydrostatic test

b) Three edge bearing test

c) Absorption test

d) Visual examination

6.10.2.12 *Sampling and Inspection*

In any consignment, all the pipes of same class and size and manufactured under similar conditions of production shall be grouped together to constitute a lot. The conformity of a lot to the requirements of the Employer/Engineer shall be ascertained on the basis of tests on pipes selected from it.

The number of pipes to be selected from the lot for testing shall be in accordance with Table 15 of IS:458.

Pipes shall be selected at random. In order to ensure randomness, all the pipes in the lot may be arranged in a serial order and starting from any pipe, every pipe be selected till the requisite number is obtained, or being the integral part of N/n where N is the lot size and n is the sample size.

All pipes selected shall be inspected by the Engineer for dimensional requirements, finish and deviation from straight. A pipe failing to satisfy one or more of these requirements shall be considered as defective.

The number of pipes to be tested shall be in accordance with column 4 of Table 15 of IS:458. These pipes shall be selected from pipes that have satisfied the requirements mentioned in the above clause.

A lot shall be considered as conforming to the requirements of IS:458 if the following conditions are satisfied.

The number of defective pipes shall not be more than the permissible number given in column 3 of Table 15 of IS:458.

All the pipes tested for various tests shall satisfy corresponding requirements of the tests.

In case the number of pipes not satisfying requirements of any one or more tests, one or two further samples of same size shall be selected and tested for the test or tests in which the failure has occurred. All these pipes shall satisfy the corresponding requirements of the test.

All result of tested data must be prepared by contractor at site so that the Engineer shall make decision of "fail or pass" at once. All cost for the test shall be borne by the Contractor.

6.10.2.13 *Marking*

The following information shall be clearly marked on each pipe:

a) Internal and External diameter and length of pipe

b) Class of pipe

c) Date of manufacture and

d) Name of manufacturer or his registered trade-mark or both.

6.10.3 **Jointing**

6.10.3.1 *General*

Jointing of RCC pipes shall be done as per the relevant IS standard. After jointing, extraneous material, if any, shall be removed from the inside of the pipe and the newly made joints shall be thoroughly cured. In case, rubber sealing rings are used for jointing, these shall conform to IS:5382. The pipe joint work must be done neatly and keep even slope and level for pipe laying works.

6.10.3.2 *Spigot and Socket joint (Rigid)*

The spigot of each pipe shall be slipped home well into the socket of the pipe previously laid and adjusted in the correct position. The opening of the joint shall be filled with stiff mixture of cement mortar which shall be rammed with caulking tool. This joint is used for low pressure pipe line.

6.10.3.3 *Collar Joint (Rigid)*

After laying the RCC pipes at proper alignment and gradient their abutting faces shall be coated with hot bitumen in liquid condition by means of a brush. The wedge-shaped groove in the end of the pipe shall then be filled with a tarred gasket in one length for each joint. The collar shall then be slipped over the end of the pipe and the next pipe butted well against the tarred gasket by suitable appliances approved by the Engineer so as to thoroughly compress the tarred gasket into the grooves, care being taken that the concentricity of the pipes and levels are not disturbed during this operation.

The collar shall then be placed symmetrically over the end of the two pipes and the space between the inside of the collar and the outside of the pipe filled with a mixture of cement and sand to withstand any stress and prevent any water leakage, tempered with just sufficient water to have a consistency of the semi-dry conditions, well packed and thoroughly rammed with caulking tools. The joints shall be finished off with a fillet sloping at 45^0 to the side of the pipe. The finished joints shall be protected and cured thoroughly as directed by the Engineer's representative. Any plastic solution or cement mortar that may have been squeezed into the inside of the pipe shall be removed so as to leave the inside of the pipe perfectly clean.

6.10.3.4 *Flush Joint (Internal)*

This joint shall be generally used for culvert pipes of 900 mm diameter and over. The ends of the pipes are specially shaped to form a self centering joint with an internal jointing space 13 mm wide. The finished joint is flush with both inside and outside with the pipe wall. The jointing space is filled with cement mortar mixed sufficiently dry to remain in position when forced with a trowel or rammer.

6.10.3.5 *Flush Joint (External)*

This joint is suitable for pipes which are too small for jointing from inside. This joint is composed of specially shaped pipe ends. Each end shall be butted against each other and adjusted in correct position. The jointing space shall then be filled with cement mortar sufficiently dry and finished off flush. Great care shall be taken to ensure that the projecting ends are not damaged as no repairs can be readily affected from inside the pipe.

6.10.3.6 *Spigot and Socket (Semi-flexible)*

This joint is composed of specially shaped spigot and socket ends on the RCC pipes. A rubber ring shall be lubricated and then placed on the spigot which is forced into the socket of the pipe previously laid. This compresses the rubber ring as it rolls into the annular space formed between the two surfaces of the spigot and socket, stiff mixture of cement and mortar shall then be filled into the remaining annular space with a caulking tool.

6.10.3.7 *Collar Joint (Semi-Flexible)*

This joint is made up of a loose collar which covers two specially shaped pipe ends. Each end shall be fitted with a rubber ring which when compressed between the spigot and collar, seals the joint. Stiff mixture of cement mortar shall then be filled to withstand stress and prevent any water leakage, into the remaining annular space and rammed with a caulking tool.

6.10.3.8 *Spigot and Socket Joint (Flexible)*

The RCC pipe with the rubber ring accurately positioned on the spigot shall be pushed well home into the socket of the previously laid pipe by means of uniformly applied pressure with the aid of a jack or similar appliance. The RCC pipes shall be of spigot and socket type and rubber rings shall be used, and the manufacturer's instructions shall be deemed to form a part of the tender requirements. The rubber rings shall be lubricated before making the joint and the lubricant shall be soft soap water or an approved lubricant supplied by the manufacturer.

6.10.4 **Cleaning of Pipes**

As soon as a stretch of RCC pipes has been laid complete from manhole to manhole or for a stretch as directed by the Engineer, Contractor shall run through the pipes both backwards and forwards a double disc or solid or closed cylinder 75 mm less in diameter than the internal diameter of pipes. The open end of an incomplete stretch of pipe line shall be securely closed as may be directed by the Engineer to prevent entry of mud or silt etc.

If as a result of the removal of any obstructions the Engineer considers that damages may have been caused to the pipe lines, he shall be entitled to order the stretch to be tested immediately.

Should such test prove unsatisfactory, contractor shall amend the work and carry out such further tests as are required by the Engineer.

It shall also be ascertained by contractor that each stretch from manhole to manhole or the stretch as directed by the Engineer is absolutely clear and without any obstruction by means of visual examination of the interior of the pipe line suitably enlightened by projected sunlight or otherwise.

6.10.5 **Testing at Work Site**

After laying and jointing of RCC pipes is completed the pipe line shall be tested at work site as per the following Employer's Requirement and as directed by the Engineer. All equipment for testing at work site shall be supplied and erected by contractor. Water for testing of pipes shall be arranged by him. Damage during testing shall be contractor's responsibility and shall be rectified by him to full satisfaction of the Engineer. Water used for the test shall be removed from pipes and not released to the excavated trenches.

After the joints have thoroughly set and have been checked by the Engineer and before back filling the trenches, the entire section of the sewer or storm water drain shall be proved by the contractor to be water tight by filling in pipes with water to the level of 1.50m above the top of the highest pipe in the stretch and heading the water up for a period of one hour. The apparatus used for the purpose of testing shall be approved by the Engineer. Contractor if required by the Engineer shall dewater the excavated pit and keep it dry during the period of testing. The loss of water over a period of 30 minutes should be measured by adding water from a measuring vessel at regular 10 minutes intervals and noting the quantity required to maintain the original water level. For the approval of this test the average quantity added should not exceed 1 liter/hour/100 linear metres/10mm of nominal internal diameter. Any leakage including excessive sweating which causes a drop in the test water level will be visible and the defective part of the work shall be removed and made good.

In case of pressure pipeline, the completed stretch of pipeline shall be tested for site test pressure. The site test pressure should not be less than the maximum operating pressure plus the calculated surge pressure, but in no case should it exceed the hydrostatic test pressure as specified in IS:458.

All of results of test and inspection data must be prepared by contractor at site so that the Engineer shall make decision of "fail or pass" at once. All cost for the inspection shall be borne by the Contractor.

6.11 Steel Cylinder Pipes and Specials

6.11.1 **Design**

In general, the design of steel cylinder pipes with concrete lining and coating shall conform to clause 8 of IS 1916. In addition to above, in case of buried pipe line, the pipe shall also be designed for the Earth load, and traffic load.

6.11.2 **Manufacturing**

6.11.2.1 *General*

Steel cylinder pipes and specials with concrete lining and coating shall be systematically checked for any manufacturing defects by experienced supervisors and a very high standard of quality shall be maintained. The pipes and specials shall be inspected by the Engineer at site and factory, and defects noticed, if any, such as protrusions, grooves, dents, notches, etc. shall be rectified, if agreed to by the Engineer. Care shall be taken that the resulting wall thickness does not become less than the minimum specified. If the wall thickness becomes less than the minimum specified, as per Table 1 of IS:1916, the damaged portion should be cut out as cylinder and replaced by an undamaged piece of pipe at no extra cost to the Engineer. The Engineer shall at all reasonable times have free access to the place where the pipes and specials are manufactured for the purpose of examining, inspection and testing the pipes and specials and for witnessing the test and manufacturing.

All tests specified either in this Engineer Requirement or in the relevant Indian Standards shall be performed by Supplier/Contractor at his own cost and in presence of the Engineer, if desired. For this sufficient notice before testing of the pipes and specials shall be given to the Engineer.

If the test is found unsatisfactory, the Engineer may reject any or all pipes and specials of that lot. The decision of the Engineer in this matter shall be final and binding on the Contractor.

6.11.2.2 *Materials*

All material shall conform to Clause 7 of IS:1916.

6.11.2.3 *Manufacturing Process*

Steel cylinder pipes with concrete lining and coating shall be manufactured as per Clause No.9 of IS:1916 and specials shall be manufactured as per Clause 7 of IS:7322. In case of spiral welded pipes, they shall be manufactured as per Clause 3 of IS:5504. Internal lining shall be up to the full length of the pipes and specials. However, external coating shall be done leaving about 100 mm length of the pipes and specials from their ends. The internal lining and external coating to pipes and specials shall be done at factory. Before lining/coating by concrete/mortar the surface of pipes and specials shall be thoroughly cleaned. In the event that loose mill scale, tuberculation, or an accumulation of dirt, debris, oil or grease is present, it shall be removed from the surface by hand, by machine or both and given a coating of neat cement slurry.

6.11.2.4 *Dimensions*

The clear cover to the reinforcement whether steel cylinder or cage shall be not less than 9 mm for lining of pipe/special and 12 mm for coating of the pipe/special.

The permissible tolerance for diameter and length of pipe shall be as per Clause 4 of IS:1916, whereas for diameter, arm length and angular deviation of specials the tolerance limit shall be as per Clause 6 of IS:7322.

6.11.2.5 *Workmanship and Finish*

Workmanship and finish of pipe shall conform to Clause 4 of IS:1916.

6.11.2.6 *Testing*

Each steel cylinder shall be subjected before lining/coating to a hydrostatic test under a water pressure equivalent to the test pressure in accordance with Clause 10 of IS:1916 and relevant provisions of IS:3597, provided that the whole of the area of the calculated reinforcement is used in the steel cylinder. In the case of pipes where a part of the principal reinforcement is provided in the cage, the steel cylinder shall be subjected to proportionately less hydrostatic test pressure.

Manufacturer's standard specials shall be hydrostatically tested before lining/coating. Where feasible, other specials shall be hydrostatically tested (before lining/coating) at factory. However, when this is not practicable, at the discretion of the Engineer, the unlined specials shall be tested by penetration test as per IS:3658 or other approved means.

All of results of test and inspection data must be prepared by contractor at site so that the Engineer shall make decision of "fail or pass" at once. All cost for the inspection shall be borne by the Contractor

6.11.2.7 *Penetration Test*

A suitable liquid penetrant (kerosene oil/Dye) is applied to the surface of the portion under examination and is permitted to remain there for sufficient time to allow the liquid to penetrate into any defects open at the surface. After the penetrant time, the excess penetrant which remains on the surface is removed. Then a light coloured powder absorbent called a developer is applied to the surface. This developer acts as a blotter and draws out a portion of the penetrant which had previously seeped into the surface openings. As the penetrant is drawn out it diffuses into the coating of the developer, forming indication of the surface discontinuities or flaws.

6.11.2.8 *Marking*

The following information shall be clearly marked on each pipe and special:

- Internal diameter, external diameter and thickness
- Class of pipe and special with its serial number
- Date of manufacture and
- Name of manufacturer or his registered trade mark or both

6.11.3 **Jointing**

6.11.3.1 *General*

Jointing of steel cylinder pipes and specials with concrete lining and coating be done as per the relevant IS. After jointing, extraneous material if any shall be removed from the inside of the pipe and special. The welding of joints for pipes and specials at work sites shall comply with IS:816. Electrodes used for welding shall comply with IS:814.

6.11.3.2 *Butt Welded Joint*

After pipes and specials are laid in the trench, the faces of pipes/specials shall first be tack-welded alternately at one or more diametrically opposite pairs of points. After completing tack welding, full welding shall be carried out in suitable runs following a sequence of welding portions of segments diametrically opposite. After jointing the exposed surface of the steel cylinder of pipes and specials shall be coated with M20 cement concrete of sufficient thickness so as to make it flush with the adjoining both inner and outer faces of pipes and specials. The gap in the internal lining at the joints shall be filled with cement mortar (1:2) for pipes and specials larger than 600 mm diameter. The lining/coating shall be done after the field test in the section has been successfully completed.

6.11.3.3 *Lap Welded Joint with Slip-in-ends*

In the case of pipes with plain or slip-in-ends, swaged end of the steel cylinder may be formed by heating one of its ends and expanding it or rolling it out to the required shape. The minimum depth and maximum clearance between the swaged end and the plain end of pipes for field welding shall be provided as directed by the Engineer. Lap welding shall be done from the external face at the junction of pipe and socket. After jointing the exposed surface of the steel cylinder of pipes and specials shall be coated with M20 cement concrete of sufficient thickness so as to make it flush with the adjoining both inner and outer faces of pipes and specials. The gap in the internal lining at the joints shall be filled with cement mortar (1:2) for pipes and specials larger than 600 mm diameter. The lining/coating shall be done after the field test in the section has been successfully completed.

6.11.3.4 *Flanged Joints*

The flanges for steel cylinder pipes and specials shall be as per BS EN 1092-1. Flanges shall be provided at the end of pipes or specials where valves, blank flanges etc. have to be introduced or flanged joints for the pipes are specified. The flanges shall have necessary bolt holes drilled. It might be necessary for contractor to follow the instructions and specifications given by the valve manufacturer. All bolts, nuts and packing material required for flanged joints shall be provided by the Contractor. Bolts and nuts shall conform to IS:1367 whereas rubber gasket of required thickness shall conform to IS:638.

The bolts shall be evenly tightened in comply with relevant BS standard. Random inspection shall be carried out by jointly the Engineer and the Contractor.

6.11.4 **Cleaning of Pipes and Specials**

Contractor shall ascertain that each stretch of pipeline is absolutely clear and without any obstruction by means of visual examination of the interior of pipeline suitably lighted by projected sunlight or otherwise. The open end of an incomplete stretch of pipeline shall be securely closed as may be directed by the Engineer to prevent entry of mud or silt etc.

If as a result of the removal of any obstructions the Engineer considers that damages may have been caused to the pipeline, he shall be entitled to order the stretch to be tested immediately. Should such test prove unsatisfactory, contractor shall amend the work and carry out such further tests as are required by the Engineer.

6.11.5 **Testing at Work Site**

After laying and jointing of steel cylinder pipes and specials with concrete lining and coating is completed the pipeline shall be tested at work site as per the following Employer's Requirement and as directed by the Engineer. All equipment for testing at work site shall be supplied and erected by Contractor. Water for testing of pipes shall be arranged by him. Damage during testing shall be Contractor's responsibility and shall be rectified by him to the full satisfaction of the Engineer. Water used for test shall be removed from pipes and not released to the excavated trenches.

Each section of the pipe line shall be slowly filled with clean water and all air shall be expelled from the pipeline. The pressure in the pipeline should then be raised and maintained by means of pump to the test pressure. The test pressure should not be less than 1 1/2 times the working pressure at the lowest point or the static head pressure, whichever is higher. Under the test pressure no leak or sweating shall be visible at the welded joints. The duration of test shall be not less than 24 hours. The exposed joints shall be carefully examined and all such joints showing visible leaks shall be rewelded. Any cracked or defective pipes and specials in consequences of this pressure test shall be removed and replaced by sound material by Contractor and the test shall be repeated to the satisfaction of the Engineer. Proper arrangement of thrust blocks shall be provided during pressure testing or pipe laying works.

6.12 Steel Pipework

Pipe/fitting material and dimensional standard shall conform to following:

Size mm (NB)	Material Specification (Steel)	Dimensional Standard
Pipes upto 150 mm	1239 PT, ERW, Black PT-1 HVY	1239 ERW
200 to 2400	2062	3589 – ERW 3589 for dimensions and minimum thickness. Pipe thickness shall be as per 2825
Elbows up to 25	ASTM–A 105	ANSI B 16.11 3000 # S.W.
40 to 150	ASTM-A 234 GR WPB	ANSI B 16.9
200 & above (meters)	2062	LR. BE. Sch 40 ANSI B 31.1
Coupling upto 25	ASTM-A 105	ANSI B 16.11 3000 # S.W.

Size mm (NB)	Material Specification (Steel)	Dimensional Standard
Tees 40 to 200	ASTM – A 234 GR WPB	ANSI B 16.9 BE, Sch 40
Above 200	IS 2062	IS 2825 (min. Pipe thickness)
Reducers up to 25	ASTM-A 105	ANSI B 16.11 3000 S.W.
40 to 200	ASTM-A 234 GR WPB	ANSI B 16.9 BE, Sch 40
Above 200	2062	IS 2825 (min. Thickness for larger pipes)
Flanges	2062	BS EN 1092-1
Bolts and all nuts	1367 C1 4.6/4.0 (except under-water service which shall be in SS-316)	1364
Gaskets All	638 (rubber) reinforced	3 mm thickness

Facilities shall be provided for draining the pipe system and releasing air.

The pipework layout within pump stations shall have the approval of the pump manufacturer. Fluid velocities in suction pipework leading to pumps shall not exceed 1.6 m/s. Fluid velocities in delivery pipework leading from pumps shall not exceed 2.4 m/s.

The whole of the jointing work and materials necessary to fix and connect the pipes, including adequate and efficient pipe support shall be included in the Contract. The Contractor shall be responsible for ensuring that the internal surface of all pipework is thoroughly cleaned before and during erection and before commissioning.

Cleaning shall include removal of all dirt, rust, scale and welding slag due to Site welding. Before dispatch from the manufacturer's works, the ends of the pipes, branch pipes, etc., shall be suitably capped and covered to prevent any accumulation of dirt or damage. This protection shall not be removed until immediately prior to connecting adjacent pipes, valves or pumps. All small bore pipes shall be blown through with compressed air before connection is made to instruments and other equipment. No point of passage of pipes through floors or walls shall be used as a point of support, except with the approval of the Engineer.

Hydrostatic shop test for pipes and fittings shall be as per code/standard requirement. After erection at site, complete pipes and fittings shall be hydrostatically tested for a pressure of 1.5 times operating pressure.

Flanges, if fabricated in segments shall be fully radiographed and stress relieved. If fabricated out of billets/bars by cold rolling, welded flanges shall be radiographed and normalized.

Protection for pipes laid underground shall be by coating and wrapping system giving a final coat thickness of 4.5 mm shall be employed. Such protection shall comprise 1.5 mm of coal tar primer application on a thoroughly cleaned surface, to be followed with fiber glass wraps set in coal tar enamel coats conforming to American Water Works Association specification C/203/57 for a total thickness of 3 mm. Such lining shall meet a spark test to be approved with a holiday detector of 10000 Volts.

The Contractor shall indicate on his detailed drawings what thrust blocks are required to anchor pipe work supplied by him. Particular care shall be taken to ensure that pipe work thrusts are, as far as possible, not transmitted to machinery or other associated apparatus.

Puddle flanges shall be fitted to pipes where the structure through which they pass is required to take thrust resulting from the pipe. Puddle flanges shall also be fitted where a water barrier is required. All puddle flanges shall be clearly shown on the drawings and the resultant thrust clearly indicated. Puddle flanges shall only be fitted with the prior approval of the Engineer.

Buried pipes shall in addition be designed to withstand external loading exerted by soil, water, and live loads as relevant. The external ground water shall be taken at ground level for design purposes.

Saddle type/bracket type support wherever required shall be designed and supplied for the above ground pipe lines.

All pipe joints shall be of the butt-welded type. End preparations and fabrication requirements shall generally conform to I.S. 2825. Flanges, if fabricated in segments, shall be fully radiographed and stress relieved.

Laying of welded steel pipes shall meet the requirements of I.S: 5822.

6.12.1 **Welded Joints for Steel Pipes**

Welding of joints in steel pipes shall be carried out manually by the metal arc welding process complying with AWWA Standard C206.

Before starting the welding of pipe joints in the Works the Contractor shall submit for the Engineer's approval details of the plant, methods and materials he proposes to use, including make and size of electrodes, number of runs, current strength and arrangements for air testing of individual joints.

Welding shall only be carried out by welders approved by the Engineer and each welder shall identify his work by means of a stencilled mark.

Welded joints other than for closing lengths shall be of the spherical spigot and socket type. For pipes of smaller than 600 mm diameter the pipe joint shall be welded externally. For pipes of 600 mm and larger, the pipe shall be welded internally and a sealing weld made externally.

All parts to be welded shall have loose scale, slag, rust, paint and other foreign matter removed by means of a wire brush and shall be left clean and dry. All scale and slag shall be removed from each weld run when it is completed. Pipes manufactured with longitudinal or spiral welds shall be lined up before jointing so that these welds are at least 15^{o} apart around the joint circumference.

For pipes larger than 900 mm diameter a triple run convex fillet weld shall be used. For pipes of 900 mm diameter or less a double run convex fillet weld shall be used. The minimum leg length of the fillet as deposited is to be equal to the full thickness of the pipe wall. The actual throat depth shall not be greater than 9/10th and not less than 7/10th of the minimum leg lengths as deposited. The depositing of the weld metal shall be carried out in such a manner as to ensure that all the welds have adequate root fusion and are of good clean metal free from cracks, gas holes, slag inclusions and all other impurities. The surface of the weld shall have an even contour with regular finish and shall indicate proper fusion with the parent metal. All slag shall be thoroughly removed after depositing each run of welding by light hammering with a chipping hammer followed by wire brushing. Any welds showing cracks or other cavities or in which the weld metal tends to overlap on to the parent metal without proper fusion or containing any other defects whatsoever shall be cut out and rewelded to the satisfaction of the Engineer at the Contractor's expense.

At closing lengths where two plain ended pipes are to be joined by a welded joint the gap between the two ends shall not exceed 75 mm. An external steel sleeve collar, of a thickness not less than that of the pipe itself and approximately 300 mm in length shall be placed centrally over the two ends to be jointed and the end of each pipe shall then be fillet welded to the sleeve collar in accordance with the above procedure.

No weld or adjacent parts of the pipe shall be painted prior to inspection by the Engineer.

6.12.2 Welder Performance Test

The Contractor shall submit for the Engineer's approval the names of persons whom he proposes to employ as welders with evidence that, as a minimum preliminary qualification, they have passed the qualifying tests prescribed in Clause 11 of BS 2633 and possessed certificates from an independent testing authority. The Engineer may further require any such person to perform satisfactory test welds under Site conditions and on pipes similar to those for use in the Works, before approving his employment as a welder. The Contractor shall maintain an up-to-date list of welders approved by the Engineer and if ordered by the Engineer, he shall remove from the approved list any welder whose workmanship, as demonstrated by the results of air pressure tests on individual welded joints, is below a reasonable standard of quality of consistency in the Engineer's opinion.

6.12.3 Testing of Welded Joints

Where directed by the Engineer welded joints on pipes larger than 600 mm diameter shall be subject to a nitrogen gas test after welding.

A tapped hole (approximately 6 mm diameter) shall be made in the socket end of each pipe by the Contractor and shall be fitted with a suitable non-return valve. Nitrogen, at 400 kPa pressure, shall then be pumped into the annular space between the spigot and socket and the pump disconnected.

If no drop in pressure occurs over the ensuing period of 30 minutes the test shall be deemed to be successful. If the test pressure cannot be maintained for 30 minutes all defects in the weld shall be cut back and rewelded and the test reapplied until successful. The cost of initial and subsequent testing of defective welds shall be at the Contractor's own expense.

The Contractor shall provide all items necessary for the nitrogen tests including compressor, valves, gauges and tubing.

6.12.4 **Hydraulic Losses**

The frictional losses due to water flow in pipe work shall be computed, as per the Hazen-William formula and as specified in the Central Public Health and Environmental Engineering Organisation (CPHEEO) Manual on Water Supply and Treatment, including losses in valves and specials, penstocks etc. c)Fittings, specials

For specials like reducers, bell-mouths, tees, elbows, etc, the `k' values shall be as recommended by the British Hydromechanics Research Association (BHRA), Volume 5, in the BHRA fluid Engineering Series.

6.12.5 **Pipework Protection**

All underground steel piping shall have their external surfaces protected by application of one coal tar enamel coat, wrapping of fibreglass, one more coat of enamel and a final wrap of enamel impregnated fibreglass. Pipe surface shall be thoroughly cleaned by shot or sand blasting. Primer paint recommended by the enamel manufacturer for the grade of enamel used shall be applied over this cleaned surface within four hours of cleaning. The primer paint shall be thoroughly mixed and applied as recommended by the manufacturer and the coating shall be free of bubbles, globules, drips and runs. The primer shall be thoroughly dry before enamel is applied and the latter shall not be applied later than 3 days after application of primer. First flood coat of enamel shall be overlaid by a single spiral wrap of fibreglass overlapping at least 20 mm on pipe upto 250 mm diameter and 25 mm on larger diameter pipes. Enamel shall be heated slowly in clean kettles, equipped with indicating or recording thermometers (100°C to 350°C range), to the recommended temperature. The enamel shall be stirred continuously. It shall be seen that fibreglass impregnates in the flood coat. Second coat of enamel and second wrap of bitumen impregnated fibreglass shall be applied in the same way. The total thickness of the coating shall not be less than 4.5 mm. Each end of the pipe left bare for a distance of 150 mm for welding shall be hand coated and wrapped after field welding is completed and hydro tested. Testing of pipe protection shall be done as directed by the Engineer using elcometers, coating thickness guages, bond test and holiday detectors.

For pipe work partly below ground and partly above ground the protective wrapping provided for underground pipeline shall be extended 300 mm above FGL and suitable clamps shall be provided at the end of wrapping to secure it properly.

All underground pipe work having a cover less than 0.9 m shall be encased with M 15 concrete of minimum 200 mm thick all around.

All above ground and steel pipes in galleries shall be externally painted with two coats of epoxy with minimum thickness of 180 microns for each coat.

6.12.6 **Flexibility in Pipework**

The Contractor shall provide flexibility in the pipework at joints in the main structures and shall submit proposals for the approval of the Engineer. Flexible joints or collars and cut pipes shall be allowed on all pipework where necessary to allow for some margin of error in the building work. Wherever possible, flexible joints shall be provided with tie bolts or other means to transfer longitudinal thrusts as a whole so that external anchorages may be kept to a minimum. Flexible joints shall also be provided for case of erection and future dismantling. Particular care shall be taken to ensure that pipework thrusts are not transmitted to machinery or associated apparatus. The Contractor shall indicate on his detailed drawings what thrust blocks are required.

6.12.7 **Puddle Flanges**

Puddle flanges shall be fitted to pipes where the structure through which they pass is required to take thrust resulting form the pipe. Puddle flanges shall also be fitted where a water barrier is required. All puddle flanges shall be clearly shown on the drawing and the resultant thrust clearly indicated. Puddle flanges shall only be fitted with the Engineer prior approval.

6.12.8 **Small Bore Pipes and Hoses**

Small bore pipes and hoses shall be of non-flame propagating materials. They shall be arranged for easy dismantling for cleaning where appropriate, and if screwed joint or joints formed by solvent welding are proposed for any chemical line, a sufficient number of flanged or flexible joints shall be provided to enable the pipe work to be removed in sections without working from one end to the other of a particular run. Tees and cocks shall also be provided at convenient points for the connection of a pressure water supply to flush pipe work through as required.

All pipes and hoses shall be labelled to enable individual lines to be identified throughout their run. Racks or trays shall be fixed to the duct walls or walls of tanks and buildings and the chemical pipes shall be fixed to these racks or trays with clips which can easily be removed without dismantling adjacent pipes. The Contract includes for the supply and fixing of all such racks or trays. Full details of the type of hoses, pipes and racks of trays proposed, shall be submitted at the time of tendering.

6.12.9 **Support of Pipework and Accessories**

All necessary supports, saddles, slings, fixing bolts and foundation bolts shall be supplied to support the pipe work and its associated equipment in an approved manner. Valve, meters, strainers, and other devices mounted in the pipe work shall be supported independently of the pipes to which they connect.

All brackets or other forms of supports, which can conveniently be so designed, shall be rigidly built up of steel by rivetting or welding in preference to the use of castings.

No point of passage of pipes through floors or walls shall be used as a point of support, except with the approval of the Engineer.

After the collars and boxes or other fitting have been fixed in position, the floors, walls and roof structure shall be made good by the Contractor.

6.13 Pipes Identification and Site Testing

6.13.1 Marking

Each pipe and fitting shall have cast, stamped or indelibly painted on it the following appropriate marks:

- *Nominal diameter*
- *Flow direction and line marks for installation*
- *Class reference*
- *Mass of pipe*
- *Date of manufacture and*
- *Manufacturer's name, initials or identification mark.*

Marking shall be done as per relevant IS code.

6.13.2 Flanged Pipes

The gaskets used between flanges of pipes shall be compressed fibre board or natural/synthetic rubber conforming to IS:638, of thickness 3 mm. The fibre board shall be impregnated with chemically neutral mineral oil and shall have a smooth and hard surface. Its weight per square metre shall be not less than 112 g/mm thickness.

Each bolt should be tightened a little at a time taking care to tighten diametrically opposite bolts alternately. The practice of fully tightening the bolts one after another is highly undesirable. The bolts shall be of mild steel unless otherwise specified.

6.13.3 Cleaning of Pipes and Fittings

The Contractor shall ascertain that each stretch of pipeline is absolutely clear and without any obstruction by means of visual examination of the interior of pipeline suitably lighted by projected sunlight or otherwise. The open end of an incomplete stretch of pipeline shall be securely closed as may be directed by the Engineer to prevent entry of mud or silt etc.

If as a result of the removal of any obstructions the Engineer considers that damages may have been caused to the pipeline, he shall be entitled to order the stretch to be tested immediately. Should such test prove unsatisfactory, contractor shall amend the work and carry out such further tests as are required by the Engineer.

6.13.4 **Testing at Work Site**

After the pipes and fittings are laid, jointed and the trench partially backfilled except at the joints the stretch of pipe line as directed by the Engineer shall be subjected to pressure test and leakage test. Where any section of the pipeline is provided with concrete thrust blocks or anchorages, the pressure test shall not be made until at least five days have elapsed after the concrete was cast. If rapid hardening cement has been used in these blocks or anchorages, the tests shall not be made until at least two days have elapsed.

Each section of the pipe line shall be slowly filled with water and all air shall be expelled from the pipe by tapping at points of highest elevation before the test is made and plugs inserted after the tests have been completed. The specified test pressure based on the elevation of the lowest point of the line or section under test and corrected to the elevation of the test gauge, shall be applied by means of a pump connected to the pipe as directed by the Engineer.

The duration of test shall not be less than 5 minutes. The exposed joints shall be carefully examined and all such joints showing visible leaks shall be recaulked until water tight. Any cracked or defective pipes and fittings in consequence of this pressure test shall be removed and replaced by sound material by Contractor at no extra cost to the Engineer and the test shall be repeated to the satisfaction of the Engineer.

After the satisfactory completion of pressure test, the section of pipe line shall be subjected to leakage test. The duration of test shall be 2 hours. No pipe installation shall be accepted until the leakage is less than the number of cm3 /h as determined by the formula:

$$q_L = \frac{ND\sqrt{P}}{3.3}$$

Where,

q_L	=	The allowable leakage in cu. m/hr
N	=	Number of joints in the length of the pipeline
D	=	Diameter in mm, and
P	=	The average test pressure during the leakage test in kg/sq.cm

Should any test of pipe laid indicate leakage greater than that specified above, the defective joints shall be repaired by Contractor at no extra cost to the Engineer until the leakage is within the specified allowance.

Necessary equipment and water used for testing shall be arranged by Contractor at his own cost. Damage during testing shall be Contractor's responsibility and shall be rectified by him at no extra cost to the Engineer. Water used for testing shall be removed from the pipe and not released in the excavated trenches.

After the tests mentioned above are completed to the satisfaction of the Engineer, the backfilling of trenches shall be done as per the Employer's Requirement specified elsewhere.

6.14 Unplasticised PVC Pipes and Fittings

Unplasticised polyvinyl chloride pipes, fittings and specials, gaskets shall be conforming to the below mentioned Indian Standards / BS 4346: Part 1for potable water.

IS:4985	Unplasticized PVC pipes for potable water supplies
IS:12235	Methods of test for unplasticized PVC pipes for potable water supplies
IS:5382	Rubber sealing rings for gas mains, water mains and sewers
IS:7328	High density polyethylene materials for mouldings and extrusion
IS:10151	PVC and its copolymers for its safe use in contact with foodstuffs, pharmaceuticals, and drinking water
ISO: 2045	Single socket for uPVC and uPVC pressure pipes with elastic sealing ring type joints - Minimum depth of engagement
ISO: 3603	Fittings for PVC pipe with elastic sealing ring joints pressure test for leakproofness

The pipes shall be of the spigot and socket type with approved gasket type flexible joint.

Where PVC pipes, fittings and specials are to be connected to Ductile iron, stainless steel or steel pipes, 'Viking Johnson' type flange adaptors or stepped couplings shall be used.

6.15 Rubber Hosing

Rubber hosing shall conform to BS 5119, Type 2. It shall be capable of handling chlorine and sulphur dioxide solutions at a working pressure of 12 bar.

6.16 Copper Tubes and Fittings

Copper tubing and fittings for work above ground level shall comply with BS 2871 and BS 864: Part 2 respectively and be jointed with capillary joints. For underground location the copper pipe shall be to BS 2871: Part 1.

6.17 Flanged Joints

All flanges shall comply with BS EN 1092-1. The nominal pressure rating for particular flanges shall be at least equal to the highest pressure rating of the pipes or fittings to which they are attached, but with a minimum nominal pressure of PN 10. All flanges shall be provided with all necessary nuts, bolts, washers and gaskets. In general, valves shall have flanged body ends.

All flanged joints which are buried or in chambers shall be protected with Densomastic and Densotape wrapping, applied in accordance with the manufacturer's instructions.

Flanges shall be installed on the pipes in the factory and field welding of flanges shall only be allowed with the approval of the Engineer.

Where pipework outside pumping stations and surge vessel chambers is cathodically protected, an insulated flange shall be incorporated at the first flange inside the structure. These flanges shall be tested to ensure that electrical insulation is achieved.

6.18 Gaskets and Joint Rings

Joint rings shall be manufactured to conform to BS 2494 or relevant Indian Standard and shall be of chloroprene rubber or other approved synthetic material suitable for temperatures up to $80^{o}C$.

Gaskets may be inside the bolt circle type and shall comply with BS 4865: Part 1. Alternatively the gasket shall be to the full diameter of the flange, drilled to suit the appropriate bolt provisions.

Chloroprene rubber with a hardness of 71 to 80 IRHD shall be used.

Joints shall be made in accordance with manufacturer's instructions or as specified herein.

Until immediately required for incorporation in a joint, each rubber ring or gasket shall be stored in the dark, free from the deleterious effects of heat or cold, and kept flat so as to prevent any part of the rubber being in tension.

Only lubricants recommended by the manufacturer shall be used in connection with rubber rings and these lubricants shall not contain any soluble constituent, shall be suitable for the climatic conditions at the Site and shall contain an approved bactericide.

After cleaning the flanges the gaskets shall be fitted smoothly to the flange and the joint shall be made by tightening the nuts to finger pressure first. Thereafter the final tightening of the nuts shall be made by gradually and evenly tightening bolts in diametrically opposite positions using standard spanners.

Graphite grease shall be applied to the threads of bolts before joints are made.

6.19 Flexible Couplings and Flange Adaptors

Flexible couplings and flange adaptors shall be of the Viking Johnson or similar approved pattern and be assembled in accordance with the manufacturer's instructions and protected, if buried or in chambers with Densomastic and Densotape wrapping applied in accordance with the manufacturers' instructions. Flexible joints shall be harnessed or tied where necessary.

6.20 Storage & Shipment

6.20.1 Protection of Pipes and Fittings for Shipment

Except where otherwise specified all items shall have received their complete protective coatings before dispatch from the manufacturer's works and shall be additionally protected by approved means for the period of transit, storage and erection, against corrosion and accidental damage.

For the protection of pipe linings and in particular for protecting cement mortar linings from drying out, protective metal or timber discs shall be fitted over the ends of pipes and fittings. Similar timber protective discs shall be attached to all flanges of pipes and fittings, by means of bolts specifically provided for the purpose and which shall be discarded when the item is incorporated in the Works. The sleeves and flanges of flexible joints shall be wired together in suitable bundles.

6.20.2 Storage of Pipeline Materials

Pipes and fittings shall be stored raised off the ground, and shall be carefully supported, cushioned and wedged. Pipes shall not rest directly on one another and shall not be stacked more than four pipes high or two pipes high in the case of pipes of 500 mm diameter or over. Special care shall be taken to ensure that flexible pipes are cradled and supported in a manner that prevents any distortion of the pipes.

Couplings and joints (and all components thereof) and other similar items shall be stored in dry conditions, raised from the ground in sheds or covered areas.

Storage areas shall be carefully set out to facilitate unloading, and checking of materials with different consignments stacked or stored separately with identification marks clearly visible.

Where items to be stored have a limited shelf life or require special storage arrangements, the method of storage shall be to the approval of the Engineer and in accordance with the manufacturer's instructions.

All pipes and fittings supplied as spares shall have end covers which are proof against the entry of sand and vermin. Mortar lined pipes and fittings shall have end covers which form a complete seal, provision being made to accommodate the effects of temperature changes. Pipes and fittings supplied as spares shall have a temporary white external finish and shall be stored sheltered from the direct rays of the sun.

End covers and protection shall not be removed until incorporation of the pipes and fittings into the Works.

6.20.3 Transportation of Pipes and Fittings

Any vehicle on which pipes are transported shall have a body of such length that the pipes do not overhang. Large pipes shall be placed on cradles and the loads properly secured during transit. The pipes shall be handled in accordance with the manufacturer's recommendations.

Approved slings shall be used and all hooks and dogs and other metal devices shall be well padded. Hooks engaged on the inner wall surface at pipe ends shall not be used. Steadying ropes shall be employed. The positions of lifting slings shall ensure that stresses and tendency towards deformation in the pipes are kept at a minimum.

Pipe handling equipment shall be maintained in good repair and any equipment which in the opinion of the Engineer may cause damage to the pipes shall be discarded. Under no circumstances shall pipes be dropped, be allowed to strike one other, be rolled freely or dragged along the ground.

6.21 Inspection of Pipes and Fittings

Before incorporating into the Works each pipe shall be brushed out and carefully examined for soundness. Damaged pipes, which in the opinion of the Engineer cannot be satisfactorily repaired, shall be rejected and removed from Site.

Damage to pipe coatings or linings shall be repaired to the satisfaction of the Engineer.

6.22 Built-in Pipework and other Plant

The pipes and other Plant in water retaining structures shall, wherever possible, be built in as the work on the structure proceeds. The Contractor shall ensure that delivery of the requisite pipe work and other Plant is in accordance with the requirements of the programme.

Where a pipe subject to thrust passes through a concrete structure or where an external seal is required, a puddle flange shall be used. The puddle flange dimensions shall be to BS EN 1092-1 but shall be undrilled. The exterior of the pipe shall be cement washed symmetrically about the puddle flange by the manufacturer for a length at least equivalent to the thickness of the wall through which it passes.

The Contractor shall be responsible through every stage of the Works for checking the correctness of the setting of built-in Plant and shall satisfy himself they are positioned in accordance with his approved drawings.

6.23 Pipe Laying

6.23.1 Carting & Handling

Pipes and fittings /specials shall be transported from the factory to the work sites at places along the alignment of pipeline as directed by the Engineer. Contractor shall be responsible for the safety of pipes and fittings/specials in transit, loading/unloading. Every care shall be exercised in handling pipes and fittings/specials to avoid damage. While unloading, the pipes and fittings/specials shall not be thrown down from the truck on to hard surfaces. They should be unloaded on timber skids with steadying ropes or by any other approved means. Padding shall be provided between coated pipes, fittings/specials and timber skids to avoid damage to the coating. Suitable gaps between pipes should be left at intervals in order to permit access from one side to other. In case of spigot socket pipes, care should be taken regarding orientation of pipes while unloading. As far as possible, pipes shall be unloaded on one side of the trench only. The pipes shall be checked for any visible damage (such as broken edges, cracking or spalling of pipe) while unloading and shall be sorted out for reclamation. Any pipe which shows sufficient damage to preclude it from being used shall be discarded. Dragging of pipes and fittings/specials along concrete and similar pavement with hard surfaces shall be prohibited.

6.23.2 **Storage**

Each stack of pipes shall contain only pipes of same class and size, with consignment or batch number marked on it with particulars of suppliers wherever possible. Storage shall be done on firm level and clean ground and wedges shall be provided at the bottom layer to keep the stack stable. The stack shall be in pyramid shape or the pipes placed lengthwise and crosswise in alternate layers. The pyramid stack shall be made for smaller diameter pipes for conserving space in storing them. The height of the stock shall not exceed 1.5 m.

Fittings/Specials shall be stacked under cover and separated from pipes.

Rubber rings shall be stored in a clean, cool store away from windows, boiler, electrical equipment and petrol, oils or other chemicals. Particularly in the field, where the rubber rings are being used, it is desirable that they are not left out on the ground in the sun or overnight under heavy frost or snow conditions.

6.23.3 **Laying**

6.23.3.1 *Excavation*

Before excavating the trench the alignment of pipeline shall be approved by the Engineer. The excavation of trenches and pits for manholes/ chambers shall be carried out in accordance with the Employer's Requirement described elsewhere and shall be done such that it does not get far ahead of the laying operation as approved by the Engineer.

To protect persons from injury and to avoid damage to property, adequate barricades, construction signs, red lanterns and guards as required shall be placed and maintained during the progress of the construction work and until it is safe for the traffic to use the roadways. The relevant Indian Standards and the rules and regulations of local authorities in regards to safety provisions shall be observed.

Suitable fencing shall be provided along the sides of trenches and pits. The posts of fencing shall be of timber securely fixed in the ground not more than 3 m apart and they shall not be less than 75 mm in diameter or less than 1.2m above surface of the ground. There shall be two rails, one near the top of the post and the other about 450mm above the ground and each shall be from 50mm to 70mm in diameter and sufficiently long to run from post to post to which they shall be bound with strong rope. The method of projecting rails beyond the post and tying them together where they meet shall not be allowed on any account. All along the edges of the excavation trenches, a bank of earth about 1.2 m high shall be formed, where required by the Engineer for further protection.

The road metal and also the rubble packing shall first be stripped off for the whole width of the trench/pit and separately deposited in such place or places as may be determined by the Engineer.

During excavation, large stones and rubble shall be separated and removed from the excavated soil and stacked separately. The material from excavation shall be deposited on either side of the trench leaving adequate clear distance from the edges of the trench and pit, or as may be necessary to prevent the sides of the trench pit to slip or fall, or at such a distance and in such a manner as to avoid covering fire hydrants, sluice valves, manholes and covers etc. and so as to avoid abutting the wall or structure or causing inconvenience to the public and other service organizations or otherwise as the Engineer may direct.

Contractor shall take into account additional excavation if any as the Engineer may require in order locating the position of water pipes, drains, sewers etc. or any other works which may be met with, in or about the excavation of trenches/pits while quoting the rates of excavation. Such service lines if met with during excavation shall be properly maintained by Contractor, by means of shoring, strutting, planking over, padding or otherwise as the Engineer may direct, and shall be protected by the Contractor from damage during the progress of the work. All precautions shall be taken during excavation and laying operations to guard against possible damage to any existing structure /pipe line of water, gas, sewage etc.

Utmost care shall be taken to see that the width of the trench at the top of pipe is not more than the minimum requirement. In case additional width is required it shall be provided only in the top portion from the ground level up to 300 mm above the top of pipe. If any extra width is provided in the area below this portion, Contractor shall have to provide remedial measures in the form of lime concrete or rubble masonry otherwise at the discretion and to the satisfaction of the Engineer. If rock is met with, it shall be removed to 15 cm below the bottom of pipes and fittings/specials and the space resulting shall be refilled with granular materials and properly consolidated. Bottom of trenches/pits shall be saturated with water and well rammed wherever the Engineer may consider it necessary to do so.

Wherever a socket or collar of pipe or fitting/ special occurs, a grip is to be cut in the bottom of the trench or concrete bed to a depth of at least 75 mm below the bed of the pipe so that the pipe may have a fair bearing on its shaft and does not rest upon its socket. Such grip shall be of sufficient size in every respect to admit the hand all around the socket in order to make the joint and the grip shall be maintained clear until the joint has been approved by the Engineer.

When welding is to be carried out with the pipes and specials in the trench, additional excavation of not more than 60 cm in depth and 90 cm in length shall be made at joints in order to facilitate welding.

The excess excavated material shall be carried away from site of works to a place up to a distance as directed by the Engineer. This shall be done immediately so as not to cause any inconvenience to the public or traffic. If the instructions from Engineer are not implemented within seven days from the date of instructions to cart the materials and to clear the site, the same shall be carried out by the Engineer at the cost of Contractor and any claim or dispute shall not be entertained in this respect.

6.23.3.2 *Dewatering*

During the excavation, if subsoil water is met with, Contractor shall provide necessary equipment and labourers for dewatering the trenches. The Contractor shall also make necessary arrangement for the disposal of drained water to nearby storm water drain or in a pit if allowed by the Engineer. In no case the water shall be allowed to spread over the adjoining area. Before discharging this water into public sewer/drain, the Contractor shall take necessary permission from the local authorities.

6.23.3.3 *Special Foundation in Poor Soil*

Where the bottom of the trench and sub grade is found to consist of material which is unstable to such a degree that in the opinion of the Engineer, it cannot be removed and replaced with an approved material thoroughly compacted in place to support the pipe properly, a suitable foundation for the pipes, consisting of piling, timbers or other materials, in accordance with relevant drawings to be prepared by the Contractor and as instructed by the Engineer shall be constructed.

6.23.3.4 *Wooden Shoring*

Contractor shall suitably design polling boards, waling and struts to meet different soil conditions that might be encountered in excavating trenches/pits. The horizontal and vertical spacing of struts shall be such that not only the sides of trenches shall be prevented from collapse but also easy lowering of pipe in trenches shall be ensured without creating undue obstructions for the excavation of the work. Any inconvenience and/or delay that might be caused in lowering pipes in trenches, as a result of adopting improper spacing of struts by the Contractor, shall be his sole responsibility. No part of shoring shall at any time be removed by Contractor without obtaining permission from the Engineer. While taking out shoring planks the hollows of any form must simultaneously be filled in with soft earth well rammed with rammers and with water.

The Engineer may order portions of shoring to be left in the trenches /pits at such places, where it is found absolutely necessary to do so to avoid any damage which may be caused to buildings, cables, gas mains, water mains, sewers etc. in close proximity of the excavation, by pulling out the shoring from the excavations. The Contractor shall not claim, on any reason whatsoever, for the shoring which may have been left in by him at his own discretion.

6.23.3.5 *Steel Plate Shoring*

Where the subsoil conditions are expected to be of a soft and unstable character in trench/pit excavation, the normal method of timbering may prove insufficient to avoid subsidence of the adjoining road surfaces and other services. In such circumstances, the Contractor shall be required to use steel trench sheeting or sheet piling adequately supported by timber struts, waling etc., as per the instructions, manner and method directed by the Engineer. Contractor shall supply pitch, drive and subsequently remove trench sheeting or piling in accordance with other items of the Engineer's Requirements.

6.23.3.6 *Boning Staves and Sight Rails*

In laying the pipes and fittings/specials the centre for each manhole/chamber or pipeline shall be marked by a peg. Contractor shall dig holes for and set up two posts (about 100 x 100 x 1800 mm) at each manhole/chamber or junction of pipelines at nearly equal distance from the peg and at sufficient distances there from to be well clear of all intended excavation, so arranged that a sight rail when fixed at a certain level against the post shall cross the centre line of the manhole/chamber or pipe lines. The sight rail shall not in any case be more than 30 m apart; intermediate rails shall be put up if directed by the Engineer.

Boning staves of 75 mm x 50 mm size shall be prepared by Contractor in various lengths, each length being of a certain whole number of metres and with a fixed tee head and fixed intermediate cross pieces, each about 300 mm long. The top-edge of the cross piece must be fixed below the top-edge of the tee-head at a distance equal to the outside diameter of the pipe or the thickness of the concrete bed to be laid as the case may be. The top of cross pieces shall indicate different levels such as excavation for pipe line, top of concrete bed, top of the pipe etc. as the case may be.

The sight rail of size 250 mm x 40 mm shall be screwed with the top edge resting against the level marks. The center line of the pipe shall be marked on the rail and this mark shall denote also the meeting point of the center lines of any converging pipes. A line drawn from the top edge of one rail to the top edge of the next rail shall be vertically parallel with the bed of the pipe, and the depth of the bed of pipe at any intermediate point may be determined by letting down the selected boning staff until the tee head comes in the line of sight from rail to rail.

The post and rails shall be perfectly square and planed smooth on all sides and edges. The rails shall be painted white on both sides, and the tee-heads and cross-piece of the boning staves shall be painted black.

For the pipes converging to a manhole/chamber at various levels, there shall be a rail fixed for every different level. When a rail comes within 0.60 m of the surface of the ground, a higher sight-rail shall be fixed for use with the rail over the next point.

The posts and rails shall in no case be removed until the trench is excavated, the pipes are laid and the Engineer gives permission to proceed with the backfilling.

6.23.3.7 *Laying of Pipes and Fittings/Specials*

All precautions shall be taken during excavation and laying operations to guard against possible damage to any existing structure/pipeline of water, gas, sewage etc. After excavation of trenches, pipes shall not be lowered unless the dimensions of trenches and bedding work for pipes at the bottom of the trenches are approved and measured by Engineer's Representative. Pipes and fittings/specials shall be carefully lowered in the trenches. Special arrangements such as cranes, tripods with chain pulley block for lowering the pipes and fittings/specials shall be made by Contractor. In no case pipes and fittings/specials shall be dropped. Slings of canvas or equally non-abrasive material of suitable width or special attachment to fit the ends of pipes and fittings/specials shall be used to lift and lower the coated pipes and fittings/specials. The pipes and fittings /specials shall be inspected for defects and be rung with a light hammer preferably while suspended to detect cracks. If doubt persists, further confirmation shall be done by pouring a little kerosene/dye on the inside of the pipe at the suspected spot. No sign of kerosene/dye should appear on the outside surface. Pipes and fittings/specials damaged during lowering or aligning shall be rejected by the Engineer.

All the pipes are to be laid perfectly true both in alignment and to gradient specified. In case of spigot and socket pipes, the socket end of the pipe shall face upstream when laid on level ground, when the pipeline runs uphill, the socket ends should face the upgrade. The laying of pipes shall always proceed upgrade of a slope. After placing a pipe in the trench, the spigot end shall be centered in the socket and the pipe forced home and aligned to required gradient. The pipes shall be secured in place with approved backfill material tamped under it except at the socket. Pipes and fittings/specials which do not allow a sufficient and uniform space for joints shall be removed and replaced with pipes and fittings/specials of proper dimensions to ensure such uniform space. Precautions shall be taken to prevent dirt from entering the jointing space. At times when pipe laying is not in progress, the open ends of pipe shall be closed by a watertight plug or other means approved by the Engineer. During the period that the plug is on, the Contractor shall take proper precautions against floating of the pipe owing to entry of water into the trench. Wherever it is necessary to deflect pipe from a straight line, either in the vertical or horizontal plane, to avoid obstructions or where long radius curves are permitted the deflection allowed at joints shall not exceed 2 ½^0. In case of pipes, with joint to be made with loose collars, the collars shall be slipped on before the next pipe is laid. The pipes shall be laid such that the marking on pipes appears at the top of the pipes.

The cutting of pipe for inserting valves, fittings, or specials shall be done in a neat and workman like manner without damage to the pipe so as to leave a smooth end at right angles to the axis of the pipe. For this purpose, pipe cutting machine shall be used.

6.23.3.8 *Thrust Blocks*

Thrust blocks shall be provided, to counteract hydraulic thrust, at places wherever directed by the Engineer.

6.23.3.9 *Jointing*

Jointing for pipes and fittings/specials shall be done in accordance with the relevant Employer's Requirement depending upon the type of pipes being used.

6.23.3.10 *Testing and Commissioning*

Testing and commissioning of pipes shall be done in accordance with the relevant Employer's Requirement.

6.23.3.11 *Backfilling*

On completion of the pipe laying operations in any section, for a length of about 100 m and while further work is still in progress, refilling of trenches shall be started by the Contractor with a view of restricting the length of open trenches. Pipe laying shall closely follow the progress of trench excavation and the Contractor shall not permit unreasonably excessive lengths of trench excavation to remain open while awaiting testing of the pipeline. If the Engineer considers that the Contractor is not complying with any of the foregoing requirements, he may prohibit further trench excavation until he is satisfied with the progress of laying and testing of pipes and refilling of trenches. Filling to a level of 300 mm above the crown of the pipe shall be done in accordance with the requirements of the clause on bedding. Care shall be taken during backfilling, not to injure or disturb the pipes, joints or coating. Filling shall be carried out simultaneously on both sides of the pipes so that unequal pressure does not occur. Walking or working on the completed pipeline shall not be permitted unless the trench has been filled with the instructed bedding and surround material up to height of at least 300 mm over the top of the pipe except as may be necessary for tamping etc., during backfilling work.

The remaining portion of the trench shall be filled in with selected excavated material free from and topsoil, vegetation or boulders and clods of earth larger than 75 mm in size. Filling shall be done in layers not exceeding 150 mm in thickness accompanied by adequate watering, ramming etc., so as to be compacted to 90% of the maximum dry density as per Part 7 of IS:2720. The water contents of the soil shall be kept as near the optimum moisture content as possible. The trench shall be refilled so as to build up to the original ground level, keeping due allowance for subsequent settlement likely to take place. The surface of the refilled excavations shall be left slightly higher than the adjacent ground and be maintained by the Contractor to a smooth even slope.

The Engineer shall, at all times, have powers to decide which portion of the excavated materials shall be used for filling and in which portion of the site and in what manner it shall be so used.

If suitable material for refilling is not available from already excavated material, the Contractor shall import material of approved quality as directed by the Engineer.

Regular measurement of the field dry density shall be taken by the Contractor at various levels in the backfilling as required by the Engineer.

No mechanical plant other than approved compacting equipment shall run over or operate within the trench until backfilling has reached its final level or the approval for the Engineer has been obtained.

Should any subsidence take place either in the filling of the trenches or near about it during the works the Contractor shall make good the same at his own cost.

Surplus excavated material shall be used to fill in any low spots above the pipeline which are identified on the Drawings or are instructed by the Engineer. Such material shall be evenly placed and compacted in layers not exceeding 200 mm thick after compaction. The method of compaction employed shall achieve not less than 90% maximum dry density as determined from IS:2720 (Part 7). Unless approved of by the Engineer, the width of areas to be filled shall not exceed 20m.

6.23.3.12 *Reinstatement of Road/Footpath*

Reinstatement of road/footpath shall be done as per the requirements of local authorities and the Employer's Requirement after completion of work.

6.23.3.13 *Clearing of Site*

All surplus materials, and all tools and temporary structures shall be removed from the site as directed by the Engineer and the construction site left clean to the satisfaction of the Engineer.

6.24 Disinfection of Water Mains

The mains intended for potable water supplies should be disinfected before commissioning them for use. Special care should be taken to ensure disinfection of new mains. Among possible sources of contamination are sewer drainage, contaminated soil in the trench, contamination from workmen or their equipment of both and unavoidable foreign material present in the trench during construction.

Education of crew members as to the need for avoiding contamination of the main during construction is fundamental. Contractors and workmen should be thoroughly familiar with all pertinent state and local requirements governing installation of mains. All sewers, water mains and other underground conduits should be located prior to construction, relocated if necessary, to prevent contamination during construction. Pipe should be strung on high ground. At all times when construction is not actually in progress, watertight plugs should be installed in all pipe openings. Gunny sack and rags are not adequate. Provision should be made to pump any other water that might collect in the trench. Special care should be taken to avoid contamination of valves, fittings, and pipe interiors, both before and during construction each of them should be inspected and, if necessary, cleaned before installation.

After pressure testing the main, it should be flushed with clean water at sufficient velocity to remove all dirt and other foreign materials in the constructed pipeline. When this process has been completed, disinfection (using liquid chlorine, sodium or calcium hypochlorite) should proceed by one of the recommended methods as described in the following clauses 6.19.1 and 6.19.2.

6.24.1 **Continuous Feed**

In this method, water from the distribution system or other approved source and the chlorine is fed at constant rate into the new main at a concentration of atleast 20 mg/1. A properly adjusted hypochlorite solution injected into the main with a hypochlorinator, or liquid chlorine injected into the main through a solution feed chlorinator and if required, booster pump may be used. The chlorine residual should be checked at intervals to ensure that the proper level is maintained. Chlorine application should continue until the entire main is filled. All valves, hydrants, etc., along the main should be operated to ensure their proper disinfection. The water should remain in the main for a minimum of 24 hours. Following the 24 hours period no less than 10 mg/1 chlorine residual should remain in the main.

The Contractor is requested to provide photo and take a record of the value of chlorine residual at starting point and after 24 hours before completion of work.

The Engineer shall jointly check the test at sites. If the value is insufficient, the disinfections work shall be repeated until satisfactory results are achieved.

Waste chlorine residual water must be neutralized before it is discharged to any drainage.

6.24.2 **Slug Method**

In this method a continuous flow of water is fed with a constant dose of chlorine (as in the previous method) but with rates proportioned to give a chlorine concentration of at least 300 mg/1. The chlorine is applied continuously for a period of time to provide a column of chlorinated water that contacts all interior surfaces of the main for a period of at least 3 hours. As the slug passes tees, crosses, etc., proper valves shall be operated to ensure their disinfection. This method is used principally for large diameter mains where continuous feed is impractical.

Regardless of the method used, it is necessary to make certain that backflow of the strong chlorine solution into the supplying line does not occur. Following the prescribed contact period, the chlorinated water should be flushed to waste until the remaining water has a chlorine residual approximating that throughout the rest of the system. Bacteriological tests as prescribed by the authorities should be taken, and if the results fail to meet minimum standards, the disinfecting procedure should be repeated and the results again tested before placing the main in service.

If continuous feed method is difficult to apply, Retention Method shall be considered as alternative way.

The area or pipe line to be disinfected shall be fed with chlorine solution from up stream under flowing water condition, and then the area shall be blocked after make sure to reaching more than 20 mg/l. The chlorine solution fed in the pipeline needs to wait for 1 day before starting measurement of residual chlorine. After 3 days later, the chlorine residual value shall be tested at sampling points at up stream and at downstream near to end to check whether the value is in range or not.

The Contractor shall provide photo and take a record of the value of chlorine residual at starting point and after 24 hours before completion of work.

The Engineer shall jointly check the test at sites. If the value is insufficient, the disinfection work shall be repeated until satisfactory results are achieved.

Waste chlorine residual water must be neutralized before it is discharged to any drainage, as approved by Engineer.

6.24.3 **Internal Cement Mortar Lining**

All pipes and fittings shall be internally lined with cement mortar in accordance with IS:11906/AWWA C602. Cement mortar lining shall be applied in-situ after pipe laying and after sectional hydraulic testing. Cement shall be Portland cement in accordance with IS:8112. Sand used for lining shall be tested with standard sieves as per IS:460 and requirements specified in IS:11906

6.24.3.1 *Surface Preparation*

The interior surface of pipe to be lined shall be cleaned to remove all rust, chemical or other deposits, oil, grease and all accumulations of water, dirt, and debris. The cleaning of the surface shall be carried out by the use of suitable chemical or mechanical means to the approval of the Engineer. The extent of cleaning shall be to the satisfaction of the Engineer.

All loose mill scale, dirt, rust, and accumulation of construction debris shall be removed from the interior of the steel pipeline. The pipeline shall be cleaned by use of power-driven cleaner incorporating revolving brushes on rotating arms.

Immediately prior to the travel of the lining machine through the pipeline, all foreign material shall be removed. This includes sand and loose mortar that might have accumulated since the work of preparation of surfaces was completed.

6.24.3.2 *Mix Proportion*

Proportion of sand to cement shall not be more than 2 parts sand to 1 part cement by weight. Mortar composing of cement, sand and water shall be well mixed and of proper consistency to obtain a dense, homogeneous lining that shall adhere firmly to the pipe surface. The water:cement ratio shall not exceed 0.5:1. The cement mortar mix shall comply with strength and density requirements specified in IS:11906/AWWA C602. No admixtures shall be permitted unless approved by the Engineer.

6.24.3.3 *Thickness of lining*

Lining shall be uniform in thickness. The lining thickness shall be as specified to IS:3589 with a negative tolerance of 1 mm and a positive tolerance of 3 mm.

6.24.3.4 *Lining Procedure*

The lining shall be placed by centrifugal method in one course by a machine travelling through the pipe and discharging the mortar at a high velocity over all pipe sections and long radius bends. The discharge shall be from the rear of the machine so that the freshly applied mortar will not be marked. The rate of travel of the machine and the rate of mortar discharge shall be mechanically regulated so as to produce uniform thickness throughout. The mortar must be densely packed and shall adhere to the pipe wherever applied.

6.24.3.5 *Surface Finish*

Mortar lining shall be mechanically trowelled except for the places where hand trowelling is expressly permitted by the Engineer.

The lining machine shall be provided with attachments for mechanically trowelling the mortar. Both the application and trowelling of the mortar shall take place at the rear of the machine so that the freshly placed and trowelled mortar will not be damaged. The trowel attachment shall be such that the pressure applied to the pipe will be uniform and produce a lining of uniform thickness with a smooth and even finished surface free of spiral shoulders. The finished surface of machine-placed and trowelled linings in pipe shall be examined according to the following procedure.

Thickness of lining shall be ascertained frequently during placing of mortar and trowelling using an approved non-destructive method.

In the stretch of pipe that has been lined and trowelled in each day's run, ten places shall be selected in straight sections of the pipe by the Engineer. In each of the ten places the thickness of the lining shall be re measured by non-destructive means as directed by the Engineer.

Defects in lining, including but not restricted to, sand pockets, voids, over sanded areas, blisters, cracked and dummy areas, and thin spots shall be removed, and the area shall be repaired to the full required thickness of the mortar lining. Defective areas encompassing the full diameter of the pipe shall be replaced by machine. Defective lining rejected at the time of lining shall be removed before initial set of the mortar. Defective lining rejected after initial set shall be replaced or repaired by the most practical method as determined by the Engineer.

Hair cracks or cracks up to 0.25 mm width and not over 300 mm in length in finished linings may be considered acceptable at the discretion of the Engineer but larger cracks shall be repaired or removed and redone all as directed by the Engineer.

6.24.3.6 *Hand Application*

Cement mortar lining of bends, specials, areas closely adjacent to valves and other such places where machine placing may not be practical shall be performed by hand. The Engineer may order the correction for any defect by hand application.

Cement mortar for hand work shall be of the same materials as the mortar for machine placed lining.

The areas to be lined shall be thoroughly cleaned as specified earlier and, if necessary, shall be moistened with water immediately prior to placing the hand-applied mortar.

Steel finishing trowels shall be used for the hand application of cement mortar, except at bends.

The outer edges of hand trowelled areas may be brushed in order to reduce the abutting offset.

All hand finishing work in a section of the pipeline shall be completed within 24 hours after completion of the machine application of mortar lining of that section. If necessary, application of mortar lining by machine shall be delayed or stopped to assure compliance with this schedule.

Hand placed mortar shall have a uniform and smooth surface with smooth transitions to adjacent machine placed linings.

6.24.3.7 *Curing*

Curing shall commence immediately after completion of the mortar lining and hand finishing of a section of pipeline. This shall, however, not be later than eight (8) hours after mixing of mortar. The lining shall be kept continuously in moist condition for a period of fourteen (14) days. During the operation of lining, finishing and curing, exterior surface of the pipe exposed to sunlight shall be sprinkled with enough water to keep the pipe cool. Open ends of pipes shall be suitably closed so as to maintain a moist atmosphere and prevent draught. Curing of mortar lining and simultaneous cooling of the pipeline externally shall be continued even beyond the period of fourteen (14) days if so directed by the Engineer.

6.24.3.8 *Tests*

Test blocks of the same material as used for the lining shall be made in 150 mm cube moulds and subjected to cube crushing tests. Each block shall be removed from its mould as soon as practicable and cured under the conditions of temperature and humidity identical with those in which the lining of the pipe is cured. The number of tests shall be at least four (4) cubes for each age and each water cement ratio for each days work. The works cube strength of the test cube shall not be less than 300 Kg/cm^2 after 28 days of curing or 170 Kg/cm^2 of seven (7) days of curing. The density of the test cube shall not be less than 2300 Kg/m^3.

6.24.4 **External Guniting**

Unless otherwise specified or stated on the drawings the pipeline to be laid underground and the exposed pipeline supported on saddles shall be cement mortar coated. Coating shall be in accordance with IS:1916. Cement shall be Portland Cement in accordance with IS:8112. The cement content shall be 600 kg/cu.m and water:cement ratio by mass shall not exceed 0.3:1. A length of 15 cm at each end of the pipe shall be left ungunited to facilitate site welding. The end faces shall be vertical.

6.24.4.1 *Mix Proportion*

Cement mortar shall consist of 3 parts sand to 1 part cement by volume. The water in the mixture shall be carefully controlled so as to attain the required strength and so that the mortar will not run, sag or segregate.

6.24.4.2 *Thickness of coating*

The minimum thickness of the coating shall be 30 mm with a positive tolerance of 3 mm and no negative tolerance. Checking of the coating thickness shall be by non-destructive means such as ultrasonic thickness gauge.

6.24.4.3 *Surface Preparation*

The surface of all pipes to be coated with cement mortar shall be thoroughly cleaned by hand or by sand steel grit blasting if necessary. After cleaning the external surface of pipe shall be given a coat of cement wash.

All oil and greases on the surface of the metal shall be removed thoroughly by flushing and wiping using suitable solvents and clean rags. The use of dirty or oily rags shall not be permitted. All other foreign materials shall be moved by buffing or by scrapping and wire brushing. After cleaning, the pipe shall be protected and maintained free of all oil, grease and dirt that might fall upon from whatever source until the pipe has received its cement mortar coating.

If blasting is necessary, all metal surfaces shall be thoroughly blasted to bright metal. Blasted surface which acquire a coat of rust shall be cleaned/reblasted as directed by the Engineer

6.24.4.4 *Reinforcement*

Reinforcement for the coating shall comprise of 50 x 50 x 3 mm wire mesh conforming to IS:1566 and 8 mm diameter bar to IS:1786. The mesh sheets shall overlap each other by a minimum of 100 mm and be tied with mild steel wire at 200 mm intervals. The reinforcement shall be held off the pipe wall by a series of required number of equally spaced 8 mm diameter reinforcement bars which shall run the full length of the coating. Clear cover to the reinforcement shall be in accordance with IS:1916.

6.24.4.5 *Application*

The pressure in the lower chamber of 'Cement Gun' shall be sufficient to produce a nozzle velocity of 115 to 150 m/sec when a tip with 19 mm opening is used. The compressor used shall be of an adequate capacity to maintain a pressure of at least 2.8 kg/cm^2 at the gun end. The nozzle shall be held at such a distance (65 to 100 cm) and position so that the stratum of flowing materials shall impinge as nearly as possible at right angles to the surface being gunited. All deposits of loose sand shall be removed prior to placing any layer of gunite. Gunite shall be shot in one coat to the specified thickness. Every precaution shall be taken to prevent the formation of sand pockets and if any develop, they shall be cut out and replaced with satisfactory machine placed material. No hand patching shall be allowed. The Contractor shall apply the coating in such a manner that no sloughing shall occur at any time during or following its application.

Gunite shall be placed in the top and sides of the pipe, then screeded to a uniform thickness and the ground lines or blocks removed. All rebound and waste materials shall then be removed by air blowing and gunite placed in the bottom of the fittings and screeded. When completed, the coating shall be concentric with the barrel of an even thickness. The entire surface shall then receive a final flash coat of gunite and shall be steel towelled to a true surface equal in smoothness to the spun lining in such a manner not to impair the bond between mortar and steel plate. The guniting and surface finishing shall complete in set and shall be applied continuously without the use of construction joints. In case, for any reason whatsoever, the cement does not adhere to the walls of pipes and sloughs off, swabbing the pipe with cement slurry shall not be permitted.

If for any reason it is necessary to interrupt the placing of the gunite for a length of time that will result in the material taking a permanent set, a square shoulder shall be formed at the ends of the sections and/or elsewhere by shooting against a back or by working with a trowel or other suitable tools the irregular edges of the material last placed to a clean unbroken surface face perpendicular to the pipe that will provide a suitable connection or construction joint between such material and the material to be placed subsequently. When performing this work, care shall be taken not to shatter or disturb the material remaining in place or disturb the embedded wire mesh. Before placing fresh material against the surface of such joints, they shall be carefully cleaned and wetted to ensure a good bond between the fresh material and that previously applied.

The ungunited portion at the ends of the pipe lengths left for the purpose of field welding shall be coated with M15 concrete by hand after the field welding and hydraulic testing are completed.

6.24.4.6 *Curing*

After the mortar has set, but not later than twelve (12) hours after application of the coating, curing shall be commenced. Coating shall be kept continuously moist and in the shade for at least 14 days.

6.24.4.7 *Inspection*

Pipe coatings shall be inspected prior to transport to laying site. Broken, defective or otherwise unsatisfactory areas may be rejected at any time during construction. All defective areas shall be made good to the satisfaction of the Engineer. Coating cracks over 0.25 mm wide or over 500 mm long shall be made good.

6.24.4.8 *Tests*

Compressive strength test of concrete shall be conducted on 150 mm cubes in accordance with IS:516. The number of tests shall be at least 4 cubes for each age and each water cement ratio for each days work. The concrete mix shall have a minimum characteristic compressive strength of 25 N/mm^2 at 28 days.

7. MECHANICAL REQUIREMENTS

7.1 Introduction

This part of the Employer's Requirements sets out the general standards for mechanical Plant used by the Contractor for the Works. Reference to any specific item does not necessarily imply that such plant is to be included in the Works. All Plant used for the Works shall, unless otherwise specified, comply with the provisions of this part. However, nothing in this Specification shall remove the Contractor's obligation from drawing the attention of the Employer's Representative to any feature of the Works which is not consistent with safety, or prevent him making proposals for incorporating equipment or designs which would increase the safety of plant equipment. In case the material of construction or type specified in this document for any equipment is not suitable for the particular use, it shall be changed by the Engineer/ Employer's representative during review of the specification at the time of procurement of the equipment. The Contractor shall ensure that the whole of the Works as installed is safe for use by the operating and maintenance staff, and by any other persons having access thereto. Guards, electrical safety devices, thermal insulation, noise-supervision devices, written notices, safety colours and the like shall be provided where necessary during erection permanently. The equipment layouts shall provide easy and safe assess to all operating devices, free from hazardous obstructions.

7.2 Noise Level and Vibration Limits

The noise level produced by any equipment like pump sets, blowers, compressor sets, etc. shall not exceed 85 dBA measured at a distance of 1.0 m from the outer surface of the equipment. At the time of operation, the mechanical vibration shall not exceed the limits given in Table 7.1, at recommended points of measurement as per ISO 10816:1995.

Table 7.1: Vibration Limits

Equipment	Velocity of Vibration mm/sec
All rotating equipment not having reciprocating parts with motor kW less than or equal to 15 kW	1.12
All rotating equipment not having reciprocating parts with motor kW more than 15 KW and less than or equal to 75 kW	1.8
All rotating equipment not having reciprocating parts with motor kW greater than 75 kW	2.8

7.3 Design Criteria for Pumping Stations

The submergence shall be based on Hydraulic Institute Standard and American National Standards for Intake. A baffle wall or other suitable corrective arrangement as recommended in Hydraulic Institute Standard, Pump handbook by Karassik or other recognised literature shall be provided in the suction sump to break vortices.

Level switches and indicators shall be provided for automatic start and stop operation of pumps.

Necessary switches/alarms required for safe operation of plant shall be provided. Instruments provided shall be compatible with SCADA/DCS.

The clearance between pumps/piping/valves shall be not less than 900 mm. The total head of the pump shall be selected considering combined flow and mean design level in the wet well for normal conditions of operation, and checked for entire operating head range for satisfactory operation under extreme conditions of operation i.e. single pump operation at maximum WL and all duty pump operation in parallel corresponding to lowest WL. The pump capacity and head shall be selected such that the total pump output is as per design flow and the pump is suitable for entire head range.

A minimum 15% margin over the power input to pump at duty point or 10% margin above maximum power input to the pump over entire operating head range, whichever is higher shall be kept while selecting the motor rating.

Flanged pipe shall be provided at pump delivery. The pump delivery pipe shall be connected from side of the header. Dismantling joint suitable for pump duty shall be provided at pump delivery valves for ease of installation and dismantling.

Pump delivery butterfly valves shall be with electric actuators as these are to be opened and closed when pumps are started and stopped.

Quick closing dual plate check valve shall be provided at pump delivery pipe to prevent back flow. The check valve shall be located between pump and delivery valve.

Electrically operated travelling (EOT) crane or manually operated travelling (HOT) crane shall be provided as specified.

Ventilation shall be provided for the pumping stations based on six air changes per hour or to restrict temperature rise to 5^0C above the shed temperature considering the heat dissipation of motor and installed equipment.

The design, materials, construction, manufacturing, inspection, testing and performance of all equipment shall comply with all currently applicable statues, regulations and safety codes where the equipment is to be installed. The equipment shall also conform to the latest applicable Indian or equivalent standards for the type of water to be handled. Other International standards are also acceptable, if these are established to be equal or superior to the listed standards. Nothing in this specification shall be construed to relieve the Contractor of his responsibility to provide the appropriate equipment in all respect for the use.

7.4 Pumps

The pump shall be centrifugal or VT pump as specified. Pumps shall be selected taking into account the fluid being pumped, using appropriate IS or international standard as appropriate.
Baffle wall shall be provided in the suction sump to prevent the sucking of air by the pumps when free fall of liquid occurs. Level switch and indicators shall be provided for automatic start and stop operation of pumps. Necessary switches/ alarms required for safe operation of plant shall be provided. Instruments provided shall be compatible with SCADA/DCS, when implemented in future.

The clearance between pumps / piping / valves shall be not less than 1000 mm. + 5% margin on the pump capacity shall be provided for all the pumps. The total head of the pump shall be selected considering peak flow and maximum design level in the wet well for normal conditions of operation, and checked for satisfactory operation under extreme conditions of operation. The pump capacity and head shall be selected such that the total pump output is in excess of the design flow to ensure free flow at all flow conditions.

Flanged connection will be provided at pump delivery. The pump delivery pipe will be connected from side of the header.

Pump delivery Butterfly valves will be with auto actuators as these are to be opened and closed remotely when pumps are started and stopped for valves mainly bigger than DN 400 mm.

Quick closing Dual Plate check valve will be provided at pump delivery pipe to prevent back flow. Pumping stations requiring handling equipment up to 1 ton will be with manually operated travelling crane/hoist. Pumping stations requiring above 1 ton will be with electrically operated travelling crane (EOT).

Minimum velocity in rising main shall be 0.6 m/sec while operating one pump and maximum 2.0 m/sec while operating all working pumps will be ensured.

Electromagnetic full-bore Flow Meter, Dual Plate check valve, Butterfly valve with actuator (where required), and air valves (where needed) shall be provided on rising main outside the pumping station.

Ventilation shall be provided for the pumping station based on 6 air changes per hour.

The design, materials, construction, manufacturing, inspection, testing and performance of all equipment including pumps shall comply with all currently applicable statues, regulations and safety codes in the locality where the equipment will be installed. The equipment shall also confirm to the latest applicable Indian or equivalent standards. Other International standards are also acceptable, if these are established to be equal or superior to the listed standards. Nothing in this specification shall be construed to relieve the Contractor of this responsibility. Pumps shall be designed so that the impellers and other accessories of the pump is not damaged due to flow reversal. All pumps (casing, shaft and impeller) in contact of seawater shall be made of super duplex steel with PREN>41 and for potable water with SS316.

For calculating the pump head, at-least 10% margin shall be taken over the pipe frictional losses.

List of Applicable Standards

IS: 1710 : Vertical Turbine Pumps for clear cold fresh water.

IS: 5120 : Technical requirement of rotor dynamic special purpose pumps.

HIS : Hydraulic Institute Standards U.S.A.

API: 610 : Centrifugal pumps for general refinery purposes.

IS: 1520 : Horizontal Centrifugal Pumps for clear cold fresh water.

IS: 5639 : Pumps Handling Chemicals & corrosion liquids.

IS: 5659 : Pumps for process water

ISO 5199: Technical specifications for centrifugal pumps -- Class II

ISO 9906: Roto dynamic pumps - Hydraulic performance acceptance tests -- Grades 1, 2 and 3

IS 9137: Code for acceptance tests for centrifugal, mixed flow and axial pumps - Class C

ASTM-l-165-65- Standard Methods for Liquid Penetration Inspection

In case of any contradiction with aforesaid standards and the stipulations as per technical specifications as specified hereinafter the stipulations of the technical proposal shall prevail unless the proposed material or type of the item is inferior to the aforesaid standards.

7.4.1 **Centrifugal Pumps**

Pumps shall generally comply with the requirements of standard codes as above. Pumps shall be so selected as to have a maximum capacity of not less than 125% of the rated capacity. Pump sets shall be suitable for the required duty conditions and shall be designed and constructed for 24-hours' continuous duty at full load.

Each pump shall be subject to performance test at the manufacture's work under near actual site conditions as far as possible as per ISO 9906.

7.4.1.1 *Design Features*

The pumps shall be designed for continuous operation at any point of the head capacity curve between 25% and 125% of pump rated flow without undue vibration or overheating

Centrifugal pumps shall have stable head/quantity characteristics, which fall continuously from the maximum pressure at closed valve conditions. The design speed of any pump shall not exceed 1500 rpm (synchronous).

Pumps of a particular category shall be identical and shall be suitable for parallel operations with equal load distribution. The head Vs Capacity and BHP Vs Capacity Characteristics should match to ensure load sharing and trouble-free operations throughout the range. Components of identical pumps shall be interchangeable.

The pump shall preferably horizontal split casing with double suction impeller. Horizontal end suction pump shall be accepted in exceptional cases and only when horizontal split casing pumps are not in manufacturing range. The number of stages should not exceed two numbers.

The direction of rotation shall be clearly marked on the pump. Waterways through the pump shall be smooth in finish and free from recesses and obstructions. Impeller passageways shall be as large as possible. The leading edges of the impeller vanes shall be rounded and smooth.

Water velocities in the pump suction side shall not exceed 1.5 m/s and on delivery branches of a pump the velocity shall not exceed 2.0 m/s and within working range there shall be no discernible noise due to hydraulic turbulence or cavitation within either the pump or its associated pipe work and valves.

The NPSH requirements of the pumps, based on the 3% output drop criterion shall be at least 2 m less than the NPSH available at every working condition.

Pumps shall run smooth without undue noise and vibration. Noise level produced individually or collectively shall not exceed 65 dB(A) measured at a distance of 1.0 meters from the source in any direction.

All parts exposed to wear shall be adequately protected by means of renewable sleeves, bushes, wear rings etc. which shall be arranged for easy inspection, adjustment, or replacement without removal of the pump casings, pipe work etc. or the need to disturb the drive shaft alignment.

The pump thrust shall be taken by a combined thrust and radial type bearing assembly capable of taking the weight of the moving parts and the hydraulic loads under all conditions of operation with a minimum life of 100000 hours.

The pump casing and other parts of the pump subject to pressure shall be hydraulically tested by the manufacturer to at least one and a half times the shut off head.

Integral inlet and discharge flanges shall be provided and integral lifting lugs shall be incorporated. Facilities shall be provided for the removal of air during priming and for draining. The pump may be fitted with mechanical seals or conventional soft packing. The arrangement shall be designed for easy adjustment and removal of the seal. When soft packed glands are used, suitable means shall be provided for collecting and preventing splashing of the gland leakage water. Drainage and gland leakage water shall be piped into the building drainage system. The shafts of pumps fitted with conventional packed glands shall be fitted with removable gland sleeves.

The rotating element of the pump and the motor shall be readily removable from the pump casing without the need to disconnect the adjoining pipework. The pump casing and other parts of the pump subject to pressure shall be hydraulically tested by the manufacturer to at least one and a half times (1.5 times) the maximum working pressure.

Rotating assemblies of pumps of 100 mm diameter inlet and over shall be statically and dynamically balanced and shall be designed so that the first critical speed is at least 50% greater than the maximum operating speed.

Lubrication arrangements shall be so designed that there is no contamination of the pumped fluid.

The pumps shall be horizontally mounted complete with drive motor on a common base plate. The pump/drive coupling shall be of flexible rubber bushing to facilitate removal of the pump rotating element and bearing housing without dismantling the pump casing, adjoining pipe work or drive motor. End suction pumps may be used for filter backwash, chlorination motive water and service water pumping applications etc.

The dimensions of the pump shall be metric conforming to applicable IS. The velocity at the entrance to the pump impeller shall not exceed 3.5 m/s. The bedplate shall be of substantial fabricated steel construction with floor fixing bolt holes ready drilled. All holding down bolts etc. shall be supplied with the units.

The pumps and associated pipe work shall be, wherever possible, arranged so that air can be completely expelled during priming. Where this is not possible, facilities shall be provided for the removal of the trapped air. Adequate facilities shall be provided for drainage of the pumps for inspection purposes.

Tapping shall be provided at both the suction and discharge flanges for pressure gauge equipment.

The minimum motor rating shall be larger of the following:

a) 115% of the power requirement by pump at duty point

b) 105% of the power input within any operating point between minimum and maximum resistance curves.

7.4.1.2 *Construction Features*

The pump shall be single stage double suction (split casing) type. Thrust bearing antifriction type at one end to take up thrust, should be provided in addition to bush bearings, if required.

In addition to static balancing, impeller and balancing drum shall be balanced dynamically at or near the operating speed. The impeller shall be keyed to the shaft and held tight. The impeller/s shall be independently retained against thrust (no applicable at submersible pumps). In case of impellers which are held tight by lock nuts and washer, the direction of threads of the shaft and nut shall be such that the nut shall tend to get tightened when the impeller is in motion. Pump shall be provided with renewable type casing ring.

Pump having capacity 1,000 m3/h and above, in case pump is provided with impeller wearing ring in addition to casing ring. The hardness of impeller ring shall be 50 BHN higher than that of casing ring.

Individual impellers and completed rotor assembly shall be subject to static and dynamic balancing test (as per ISO 1940 or JIS 0905 G6.3 or equivalent).

The casing shall be tested to withstand a pressure of 1.5 times the shut off pressure or twice the rated pressure whichever is higher. Delivery flange shall be as per ANSI B16.5

Bearing shall be oil-lubricated or grease-lubricated and shall have a life of 100,000 hours of working. In case of oil-lubricated bearing, constant oil leveler with magnetic drain plug shall be provided Replaceable shaft sleeves shall be provided to protect the shaft where it passes through stuffing box Stuffing box shall be of such design that it can be repacked without removing any part other than the gland and lantern ring. Mechanical seals shall be provided if needed. If required, a flushing line shall be furnished, complete with strainer and orifice, from the pump discharge to the sealing face. When pumping liquid is not suitable for this purpose, a flushing connection shall be provided so that it can be connected to an external source. Auxiliary piping and plan shall be in accordance with Appendix - D of API 610.

For better efficiency Special Surface Treatment shall be provided to the inner surface of pump casing, if it is required for design conditions. The coating used for bringing about efficiency improvement shall be polymer-based system, which is a cold cured highly modified chemically resistant, two-pack resin system filled with stabilizing enforcement to improve flow characteristics

The casing shall be provided with priming funnel and air release vent, Tapping shall be provided for installing suction and delivery pressure gauges. Each pump should be provided with combination gauge on suction side and suitable pressure gauge on delivery side. Gland leakage shall be laid to the channel provided in the pump house by bleeding SS-316L pipes.

All forging and casting shall be subject to 100 % UT or RT and MPE or DPT check, all welding subject to 100% UT or RT as per ASME sec VIII.

Impellers

Impeller shall be double suction enclosed type/ semi enclosed as per usage specified, and balanced both statically and dynamically. Renewable wearing rings shall be provided on both impeller and casing, when required.

Pump Shaft

The critical speed of the pumps shall not be less than 130% of the normal operating speed of the pump.

The shaft shall be of one-piece construction solid type and will be designed to take all types of loads such as torsion, tensile, bending and dynamic etc. The pump shaft shall be hard chrome plated steel or alloy steel (SS-420) for pumps not in contact with seawater /brine. Super-duplex PREN > 41 shall be used for pumps in contact with seawater / brine as per manufacturer's standard. Sleeves shall be of stainless-steel SS 316 L. The shaft be ground and polished to final dimensions and shall be adequately sized to withstand all stress from rotor weight, hydraulic loads, vibration and torque coming during operations.

Shaft Sleeves shall be fastened to the shaft to prevent any leakage or loosening. Shaft and Shaft Sleeve assembly should ensure concentric rotation. The impellers and shaft sleeves shall be secured to the shaft by means of a key or keys. The impeller retaining nut shall be fitted with a locking device. For potable water, the pump casing shall be of Cast iron to IS:210 Gr.FG260, wearing rings shall be of Bronze to IS:318 Gr.LTB2 and shaft sleeve shall be of stainless steel to ASTM A 743 CA 15.

Pump Bearings

Pump bearings shall be of the antifriction type or plain bearing. The bearings shall be able to take normal thrust loads due to unbalanced hydraulic loads on the impellers plus the weight of all rotating parts of the pumps. Pump bearings shall be designed with a minimum life of 100,000 hours of continuous operations at maximum axial and radial loads and rated speed. Bearings shall be easily accessible without disturbing the pump assembly. A drain plug shall be provided at the bottom of each bearing housing.

Proper lubricating arrangements for the bearings shall be provided such that lubricating element doesn't contaminate the liquid pumped.

Flexible Coupling:

The pump shaft shall be coupled to motor shaft through flexible coupling. The coupling shall comprise pin and rubber bushes or any other better than the proposed. Each half shall be statically and dynamically balanced for transmission of the power without vibration and shall be keyed to respective shaft. The coupling halves shall have precise machined surfaces for facilitating alignment. Suitable guard for coupling shall be provided.

Base Plate (Base Frame):

The pump and motor shall be installed on common base plate, to accommodate both pump and motor. Suitable machined sole pieces shall be welded on top of base plate for mounting pump and motor. The base plate shall be constructed from steel channels with suitable coating. The base plate shall be fabricated and supplied by pump manufacturer only. Base plate and pump supports shall be constructed and the piping unit be so mounted to minimize misalignment caused by mechanical forces such as normal piping strain, internal differential thermal expansion and hydraulic piping strain, internal differential thermal expansion and hydraulic piping thrust. Suitable drain troughs and drip lip shall be provided.

Assembly and Dismantling

Assembly and Dismantling of each pump with drive motor shall be possible without disturbing the grouting base plate or alignment

7.4.1.3 *Material of Construction for Centrifugal Pumps*

For HPP, ERD booster, RO and ERD feed Booster Pumps

Pump Casing : Super-duplex PREN > 41
Pump Impeller : Super-duplex PREN > 41
Pump Shaft : Super-duplex PREN >41

For CIP, Permeate Pumps

Pump Casing : AISI316L
Pump Impeller : AISI316
Pump Shaft : AISI316

For Potable Water Pumps

Pump Casing : Cast Iron
Pump Impeller : AISI316
Pump Shaft : AISI316

Motor

Motor : Triphasic squirrel cage rotor
Nominal power (kW) : As required
Speed (rpm) : As required
Voltage : As required
Drive type : Fixed / Variable frequency (VFD)

7.4.2 Vertical Turbine Pumps

Vertical turbine pumps (VT), shall be with discharge head, column pipes and sole plate. The pump assembly includes pump and motor. The basic components of the pump are discharge head, column pipe and bowl assembly which will be combined and customized to match duty needs. The pump shall be self-water lubricated. Each column pipe shall be of maximum 1.5 m length. Column pipe shall be sized to velocity less than 2.25 m/s.

7.4.2.1 *Design Features*

The design, manufacture and performance of the VT pump shall comply with all currently applicable statues, regulations and safety codes in the locality area where the equipment will be installed. The equipment shall also confirm to the latest applicable Indian Standards as under:

IS 1710	Vertical turbine pump for clear water.
IS 5120	Technical requirements for roto-dynamic special purpose pumps.

Pumping assembly including pump and motor shall be designed to operate within vibration and temperature limits specified over the full operation range of the pump performance. Provide pump with number of stages to meet the specified and indicated performance.

Provide room and facilities for inspection, repair and adjustment. Equipment pumping assembly with all specified and required accessories including lifting arrangements and pressure gauges.

Pumps shall generally comply with the requirements of IS: 5120 and IS:9137. Pumps shall be so selected as to have a maximum capacity of not less than 125% of the rated capacity.

Pump sets shall be suitable for the required duty conditions and shall be designed and constructed for 24-hours' continuous duty at full load. The pumps shall be designed for continuous operation at any point of the head capacity curve between 25% and 125% of pump rated flow without undue vibration or overheating. The pump shall be capable of developing the required bowl head at rated capacity for continuous operation.

Pump/Pump Motor shall be suitable for withstanding reverse rotation due to back-flow of water without mechanical damage to any component of the pump. Pumps of a particular category shall be identical and shall be suitable for parallel operation without any possibility of hunting. Components of the identical pumps shall be interchangeable

For calculating the pump head, at-least 10% margin shall be taken over the pipe frictional losses.

For high flow rate above 2000 m3/h, the pump discharge header shall be kept at the ground floor of the pump house concrete building while motor and MCC to be placed at the first floor to allow more space for the maintenance of pump and motor. The load bearing mounting of the pump shall be done at the first floor.

The noise level shall not exceed 65 dBA measured at 1 m from the outline of pump set. Pumps shall be selected so as to have stable characteristics. The total head capacity curve shall be continuously rising towards shut-off, with the highest at shut off. Pumps shall operate at one of the standard motor speeds not exceeding 1000 rpm. The direction of rotation of the pumps shall be clockwise looking from drive-end. The direction of rotation shall be clearly marked on the pump. The critical speed of the pumps shall not be less than 130% of the normal operating speed of the pump. The impeller adjustment shall be such that the impellers run free in any installed condition despite extension of line shaft (caused by hydraulic down-thrust) the weight of shafting and weight of impellers. The minimum motor rating shall be larger of the following:

a) 115% of the power requirement by pump at duty point

b) 105% of the power input within any operating point between minimum and maximum resistance curves.

7.4.2.2 *Construction Features*

Pumps shall be of vertical, wet pit type complete with bowl, column and head assemblies. The bowl assembly shall consist of rotating impellers, which are housed in stationary bowls having guide vanes. The bowl shall also include the housing of the bottom pump shaft bearing. The column assembly shall consist of the column pipe to convey the liquid handled from bowl assembly to head assembly, shaft enclosing tube, if required, and shaft assemblies. If shaft-enclosing tube is called for the line shaft, bearing shall be supported from shaft enclosing tube. If shaft-enclosing tube is not specified, the line shaft bearings shall be supported from the column pipes.

Individual impellers and completed rotor assembly shall be subject to static and dynamic balancing test (as per ISO 1940 or JIS 0905 G6.3 or equivalent).

Head assembly shall consist of the base from which the column shaft assembly is suspended. The discharge can be surface discharge or an underground discharge as required.

Bell Mouth and Strainer

A bell mouth shall be fitted to the suction nozzle to limit the velocity. Net opening area in strainer shall not be less than 3 times of entrance area of bell mouth. The bowls shall be cast, free from blowholes, sand holes and other detrimental defects.

The bowls shall be equipped with replaceable wearing rings on suction side of enclosed impellers. Liquid passage shall be smooth finished and enameled. The bowls shall contain bushes to serve as bearings for the impeller shaft. In case of oil lubricated units, the discharge casing shall be provided with means to prevent the leakage of liquid into the shaft enclosing tube. Suction bell shall be designed for smooth inflow of water with minimum losses. A pump bowl /bowls shall be flanged with machined matching of faces. The bell mouth to bowl assembly, to column and to discharge case i.e. all joints shall be flanged joints.

Impellers and Shaft

The impellers shall be statically and dynamically balanced so as not to cause any vibrations during operation.

The impeller shall be of the enclosed type and shall be properly balanced dynamically. The impeller shall be properly machined, with liquid passage hand finished. Impeller shall be adjustable vertically by means of an adjusting nut in the head assembly. Open impeller shall be offered, if close type is not suitable. In such a case, the pump shall be designed to take care of the additional thrust produced.

The Impeller shaft shall be straight within 0.125 mm for 3 metres length total dial indicator reading. The maximum permissible error in the axial alignment of the thread axis with the axis of the shaft shall be 0.05 mm in 150 mm.

The shaft shall be furnished with interchangeable sections. The butting faces of shaft shall be machined square to the shaft axis and the shaft ends shall be chamfered on the edges. Couplings shall be designed with a safety factor of 1.5 times the shaft safety factor and shall have threads to tighten during pump operation. The shaft shall be properly balanced so as not to cause any vibrations during operation. Line shaft bearings shall be external water or oil lubricated or self-lubricated type. For self-water lubricated type a pre lubrication connection with all accessories shall be provided to wet the bearings. The selection of material for such bearings shall suit the quality of water to be pumped and suspension length. If shaft-enclosing tube is not specified, the shaft bearings shall be lubricated by the liquid being pumped.

The pumps shaft bearings i.e. bush bearings would be water lubricated. Extra long bearing shall be provided for suction and discharge bowls. The hardness of bush bearing shall be less by at least 50 BHN than that of shaft.

Wearing Rings

Wearing rings shall be renewable type and shall be provided for both impeller as well as bowl. These shall be held in place by screwing against rotation, press fit or locked with pins, flanged and screwed. Hardness of wearing rings shall be less by at least 50 BHN than the impeller

Lubrication System

Pumps, shall be self water lubricated.

Shaft Enclosing Tube and Column Pipe

The standard length of these shall be same as that for the shaft. No part of the column pipe shall exceed the outside diameter of bowl. The size of the column pipe shall be such that the friction loss will be limited to 0.5 M per 10 M of length at rated capacity. The column shaft shall be of Super Duplex with PREN>41 and CF>35.

Discharge Head and Motor Stool

The discharge head shall have an arrow indicating the direction of rotation of shaft. For oil lubricated type, an automatic lubricator shall be installed for electric motor driven pumps and manual or other types of lubricator for engine driven pumps. A tube tension plate shall be installed on the discharge to tighten up the shaft tubes for the purpose of aligning the shafts. A gland shall be provided at the tube tension plate to seal off any leakage from the discharge head. For water lubricated pumps, the discharge head shall have a stuffing box with a renewable bushing. The discharge elbow shall be designed to directly connect to the discharge pipe without reducer / expander.

It shall incorporate full diameter elbow, mounting flange of motor for solid shaft motor, stuffing box with renewable gland packing, & tapping for pressure gauge mounting etc. The discharge head shall be of robust construction and shall be designed to support entire load of pump assembly, water column and motor etc. & shall withstand all static, dynamic, torsional loads & hydraulic thrust imposed during operation from shut off to stipulated operating conditions and thrust due to change in direction of flow, without any vibrations. The power shall be transmitted from motor to vertical shafting through a flexible coupling. Both halves of the coupling shall be machined all over, securely keyed to their respective shafts. The pins shall be of stainless steels. The arrangement of two halves shall be suitable to check alignment and parallelism. A self-aligning thrust bearing shall be housed in the head gear adequately designed to accommodate entire weight of rotating parts and hydraulic thrust and shall be designed for 100000 hours life. The bearing shall be of oil lubricated type and shall be provided with oil level gauges and suitably positioned temperature probes. Two sets of adjustable contacts shall be provided, one for an alarm and other for tripping the water pump motor. This shall be connected to scanner panel so the digital temperature can be read out with alarm and tripping.

Motor stool shall be provided for mounting the electric motor. The motor stool shall accommodate the pump thrust bearing and non-reversible ratchet or similar mechanism to prevent pump from rotation in reverse direction.

The motor stool shall be robust construction and of either cast iron or fabricated mild steel and adequately sized with openings to work on the flexible coupling.

Sole Plate

M.S. hot dip galvanized Sole plate arrangement shall be provided under the discharge head for precise horizontal and vertical alignment. Thickness of sole plate shall not be less than 40 mm. It shall be independent of the base plate integral with the discharge head. The contact surfaces of the sole plate arrangement as under shall be machined for precise levelling and shall ensure vibration free operation of the pump.

All joints between machined contacts surfaces shall be with nut bolts/tapped studs/bolts. All contact surfaces shall be blue-matched to ensure proper contact to the extent of 60% of contact area after necessary site finish if required. The opening in the sole-plate/frame shall be of adequate size to pass the bowl assembly etc. very easily. M.S. epoxy coated channels shall be anchored in the floor ensuring complete rigidity. Entire structural fabrication & foundation arrangement shall be designed & submitted for approval. M.S. plates grouted on pump supporting R.C.C. beams are to be provided in civil structure. The anchoring of channels shall be the responsibility of pumping machinery contractor with all related works.

Air Release Arrangement

Arrangement shall be made for release of Air in the column pipes of pumps. A flanged branched tee of required size and an air release Valve shall be provided in the pipe work after discharge head for automatic air release arrangement. Size of the air-vent valve and piping shall suit the actual requirements of the installation and recommendation of the pump manufacturer. Check valve: Provide a check valve to prevent reverse rotation when stopping.

Driver

Electric motor which is directly coupled to the head shaft shall be a hollow shaft motor (unless otherwise required) with thrust bearings capable of taking thrust load developed by the pump and the dead weight of the shaft and impeller. Pump shall be complete with base plate and foundation bolts. Pumps and motors shall be mounted on a fabricated common base-frame, on the first floor of the building for large pumps. The base-frame shall be stress relieved after fabrication and machined. The base-frame shall be adequately sized and shall be suitable for fixing coupling guard. Convenient access to the fixing bolts associated with the equipment and base-frame shall be ensured.

Flexible Coupling and Guard

The flexible coupling for connecting the two shaft ends shall be of tyre type conforming to IPSS-1-01-004-95. Removable coupling guards shall also be supplied and mounted. Guards shall be sufficiently heavy and rigid to provide adequate safety.

7.4.2.3 *Materials of Construction for VT Pump and Motor*

For Seawater Application

Bowl	: Super duplex PREN >41
Suction Bell	: Super duplex PREN >41
Column pipe	: Super duplex PREN >41
Pump Impeller	: Super duplex PREN >41
Pump Shaft	: Super duplex PREN >41
Motor	: Triphasic squirrel cage rotor
Nominal power (kW)	: As required
Voltage	: As required
Drive type	: Fixed / Variable frequency (VFD)

For potable water Application:

a) Pump bowl: Cast iron ASTM A48 Class 30, free from blow- holes, sand-holes and other defect and faults.

b) Pump shaft: ASTM A126 Type 316 Stainless Steel

Impeller:

a) Type – Turbine

b) Bronze ASTM B584 C83600 or C875 or Stainless Steel 316.

c) Provide a means of impeller adjustment through a top shaft adjusting nut.

d) Dynamically balanced impeller

Suction Bell: ASTM A48 class 30 cast iron flared inlet, designed for velocity not exceeding 1.4m/sec.

Strainer: A bronze or stainless steel strainer shall be furnished at the pump suction.

Suction bell bearing: Bronze ASTM 505 Alloy 932 and shall be grease packed.

Provide a sand collar of ASTM 505 C9300 Bronze attached to shaft with stainless steel 316 set screw arrangement.

Provide a suction bowl plug or cap of cast iron.

Intermediate bowl bearings: Provide bronze ASTM 505 Alloy 932 and shall be water lubricated.

Discharge bowl: Provide flanged discharge bowl of ASTM A48 class 30 cast iron

Discharge head:

a) Type: above ground
b) Material: ASTM A48 class 30
c) Provide sole plate of cast iron ASTM A48 class 30 or fabricated steel ASTM A36.

Connections:

a) Flanged, PN 10 standards.
b) Provide pump head and base plate design to withstand all thrust conditions imposed by the pump & driver during the operation at the specified conditions and the future conditions.
c) Provide Neoprene gasket between top column flange and discharge head.
d) Provide 316 stainless steel guard & hardware.

Column and Shafting:

a) Type: flanged with open line shaft
b) Column size: the velocity shall not exceed 2.25 m/sec
c) Material ASTM A53 Grade B maximum section length of 300mm
d) Provide a section of column and shafting to accommodate one future stage.
e) Pipe thickness shall be in accordance with the AWWA standard.
f) Line shaft coupling AISI type 316 stainless steel
g) Bearing retainer: Bronze ASTM B584 Alloy 836
h) Line shaft sleeve at bearing: Type 316 stainless steel

Execution: Installation shall be done as per the manufacturer's printed instructions as specified.

7.4.3 Submersible Pumps

Submersible pumps shall be of the single entry design supplied complete with boltless self-aligning duck-foot (not applicable for drainage /sump pumps) assemblies giving automatic connection to the discharge pipe work.

Submersible pumps shall be used for thickener feed and waste wash water pumping applications.

For calculating the pump head, at-least 10% margin shall be taken over the pipe frictional losses.

The total head capacity curve shall be continuously rising towards the shut off with the highest at shut off.

Pumps shall be suitable for single as well as parallel efficient operation at any point in between the maximum and minimum system resistances.

Pumps shall run smoothly without undue noise & vibration. Noise level shall be limited to 65 dBA at 1.0 m.

The pump set shall be suitable for starting with discharge valve open or closed.

The pump set shall be capable of withstanding accidental rotation in reverse direction.

7.4.3.1 *Construction Features*

a) Pump shall be centrifugal, vertical spindle, wear resisting, and single stage type.

b) Pump casing shall be of robust construction. Liquid passages shall be finished smooth and designed as to allow free passage of solids. The volute tongue shall be filed to a smooth rounded edge.

c) Double mechanical seals shall be provided to protect the motor from ingress of liquid along the shaft. The preliminary and secondary seals shall be oil-lubricated with tungsten carbide or silicon-carbide faces and they shall be equipped with an electrical monitoring system for seal failure detection, for pumps higher than 50 kw. Sensors are to be provided to detect if leakage of liquid into the oil housing is above 30 % concentration.

d) Impeller shall be non-clog enclosed type with smooth blunt edges and large waterways to allow free passage of the large size solids. It shall be free from sharp corners and projections likely to catch and hold rags and stringy materials. The number of impeller vanes for pumps up to 1000 m3/hr shall be limited to two and shall be limited to three for the pumps higher than 1000 m3/hr.

e) The critical speed of the rotor shall be at least 20% above the operating speed.

f) Pump sets shall have double bearings. The bearing life shall be minimum 100,000 hrs of operation.

g) Each pump shall be complete with a cast iron delivery connection arrangement for fixing to the concrete floor of the suction well. All necessary stainless-steel fixtures required for guiding the pumps during lifting / lowering shall be provided. The installation shall facilitate automatic installation and removal of pump without a person entering the wet well. Each pump shall be provided with a corrosion resistance material lifting chain with suitable provision for engaging the hook of the crane at 1 m interval.

h) Each pump shall be provided with an automatic coupling device for attaching the chain pulley block hook to the pump at low level, even whilst the pump is submerged, without the need for personnel to enter the well. This automatic coupling device shall easily and automatically couple and uncouple the hoist hook and be complete with necessary accessories. All links and cables shall be corrosion resistance material.

i) The submersible pumps shall be suitable for operation with or without submergence.

j) The synchronous speed shall not exceed 1500 rpm at 50 Hz supply.

Material of construction of seawater shall be mostly super duplex steel with PREN>41. Material test certificates shall be furnished by the Contractor and shall have the approval of Employer's Representative.

The submerged cable shall be a multi-core flexible cord, vulcanized rubber insulated with tough rubber sheath and outer PCP sheath to BS 6500.

Where both thermal protective and moisture-sensitive devices are incorporated within the pump, both devices shall be brought out via separate conductors within the motor cable, although one such conductor may be common.

7.4.3.2 *Materials of Construction*

The materials of construction for submersible pumps for potable water shall be as follows:

Sl. No.	Component	Material
1	Impeller	Stainless Steel: ASTM A 743 CF8M
2	Casing	Cast Iron to IS:210 Gr. FG 200 with 1.5 to 2% Nickel
3	Shaft	Stainless steel: AISI Gr.316
4	Guide System	Stainless Steel: AISI Gr. 316
5	Fasteners and Foundation Bolts	Stainless Steel: AISI Gr. 316

For seawater use, the Minimum Super Duplex PERN>41 shall be used as applicable for the above components.

Material test certificates shall be furnished by the Contractor and shall have the approval of the Engineer.
The submerged cable shall be a multi-core flexible cord, vulcanized rubber insulated with tough rubber sheath and outer PCP sheath.

Where both thermal protective and moisture-sensitive devices are incorporated within the pump, both devices shall be brought out via separate conductors within the motor cable, although one such conductor may be common.

7.4.4 Dewatering Pump

The pump motor shall be suitable for working with or without submergence in water/waste water. The motor rating shall be more than the maximum power required by the pump.
Pump shall be vertical, centrifugal, submersible, non-clog & single stage type. The pump set shall be portable with necessary hooks.
The pump shall have double mechanical seals to prevent ingress of moisture in to the motor. The pump impeller shall be mounted on the extended shaft of the motor. The pump shall be supplied with flexible hose pipe of 80 mm dia. & 50 m length. Suitable cable of 50 M length shall be supplied with the pump.

7.4.5 Sump Drainage Pumps

Sump drainage pumps shall be of the open impeller centrifugal type vertically mounted close coupled to their fully submersible electric drive motors.

Sump pumps of 3 kW and under shall incorporate an integral level detector, control and motor starter and shall be powered only with a suitably fused three phase or single phase low voltage supply and with supply isolation at the building distribution board.

Sump pumps over 3 kW shall be controlled and started from the building distribution board and be fed with a 3-phase supply. Control shall be via adjustable float level switches mounted adjacent to the pump. Min. four nos. of Drainage pumps of 125 KW to drain the inlet sump shall be provided in addition to the required drainage pumps as required for proper drainage of site.

The pumps shall be supplied with all necessary discharge pipe work, including nonreturn and isolating valves and suitable lifting gear for lowering and removing the pump from the sump. Pumps weighing 40 kg and more shall be lowered in the sump via guide rails and be located to their respective discharge pipe work with an angle flange connection and self-locating clamps.

The pump impeller shall be designed to pass solids of sizes which pass through the inlet ports of the pump and shall be capable of pumping solids of up to 20 mm diameter.

7.4.6 Progressive Cavity Pumps

These pumps shall be used for handling thickened sludge transfer and BFP feed applications.

Pumps shall be of the type in which a pumping action is generated by a helical rotating eccentrically within a resilient stator in the form of a double internal helix. The eccentric motion of the rotor shall maintain a constant seal across the stator as it travels through the pump to give a uniform positive displacement.

Pumps shall be arranged generally with a single shaft seal at the suction end. Mechanical seals shall be used. If a flexible shaft is used to accommodate the eccentric motion, a corrosion resistant shroud shall be fitted to prevent fibre build-up on the shaft. Enlarged inspection access holes shall be fitted to the suction chambers of all pumps for periodic removal of accumulated debris.

For calculating the pump head, at-least 10% margin shall be taken over the pipe frictional losses.

The shaft bearing shall be positively isolated from the fluid being pumped.

The rotor material shall be selected for corrosion and abrasion resistance for the fluid being pumped, and for prolonged service life. Hard chrome or other approved coatings shall be not less than 250 micron thickness and shall be diffused in to the base material. The rotor shall generally be single-stage and shall incorporate not less than 360° of twist, but for high-head applications, it may be necessary to use more than a single-stage. The stator shall be of a resilient material selected for chemical and abrasion resistance for the fluid being pumped.

Pump speed shall suit the application, where variable delivery output is needed; the pump shall be provided with a variable-speed drive. The size and speed range of the pump shall ensure that the highest expected duty point shall lie within the available speed range.

Pumps shall normally be driven by a fixed-speed electric motor through reduction gearing and the combined drive shall be continuously rated. Pump and motor shall preferably be mounted in-line on a common base plate. Alternatively, the drive motor may be top-mounted above the pump to minimize floor area, and shall be connected by external V-belts and pulleys. V-belt drives shall have full guards of the type that allow the belts observed without removal of the guard. Facilities shall be provided for ready adjustment of belt tension.

Coupling guards shall be provided, which shall be rigid, securely fixed, and designed so that removal is not necessary during normal operation, routine maintenance and routine inspections. All motor enclosures shall be provided with ingress protection to IP55. Motor anti-condensation heaters shall be provided and shall be suitable for use on a 220V single-phase, 50Hz supply.

All bearing shall have a B10 design life of not less than 40,000 running hours and shall be designed for loading 20% in excess of calculated maximum loading. Pumps shall be fitted with individual dry-running protection to initiate pump trip. Dry-running protection by 'under-current' monitoring or 'pipeline-intrusive' device shall not be used.

7.4.6.1 *Material of Construction for Progressive Cavity Pumps*

Pump Housing	Cl IS 210 GR. FG220 or FG260
Rotor	SS AISI 316(Hard chrome Plated)
Shaft	SS AISI 410(Hard chrome Plated)
Stator	Nitrite black
Type of drive	V belt & Pulleys
Base plate	MS fabricated with suitable coating
Seal type	Gland packing (Asbestos Free)

7.4.7 **Chemical Bulk Transfer Pumps**

Pumps shall be selected taking into account the chemical being pumped, form of chemical, wear leakage and resistance to corrosion.

For centrifugal pumps, the pump shaft shall be of stainless steel to Grade 410S21 compatible with the impeller which shall be of stainless steel ASTM A743 CF8M and the impellers and shaft sleeves shall be secured to the shaft by means of a key or keys. The impeller retaining nut shall be fitted with a locking device. The pump casing shall be of stainless steel ASTM A743 CF8M, wearing rings shall be of Bronze to IS:318 Gr. LTB2 and shaft sleeve shall be of stainless steel to ASTM A 743 CA 15. All stainless steel parts shall be hard chrome plated.

Each pump shall be provided with inlet and outlet isolating valves and where necessary, with pressure relief and non-return valves and also Pressure Gauges with stopcock.

A relief valve shall be incorporated in the delivery lines under conditions where the pump discharge pipe can be shut off or where pressure may rise to an excessive point. The relief valve shall be sized to handle the system pressure and to discharge maximum pump output freely, and shall be located in the discharge line between the pump and the first downstream isolating valve. Relief valves when used on pumps handling non-hazardous chemicals shall discharge the vented liquid to waste. When used on hazardous chemicals the valve outlet shall be piped back to the suction supply tank or bunded-area. The open end of the return pipe shall be located where it is visible, so that any relief valve leakage/operation can be detected.

Pump transferring chemicals to systems under pressure shall incorporate a pressure gauge on the pump delivery. Air cocks shall be provided for release of air where necessary.

Flushing connections shall be provided at each pump inlet and flushing shall be manual. When flushing, water shall be discharged either locally through a drain valve or to the point of application of the chemical. Facilities shall also be provided for flushing chemical pump suction and delivery manifolds and delivery lines to point of application.

7.4.8 **Chemical Dosing Pumps**

Chemical Dosing Pumps shall be piston diaphragm or mechanical diaphragm type as specified. Pumps may be simplex or duplex arrangements to suit the capacity or process requirements. The pump design shall incorporate positive stroke return. The maximum stroking speed shall not exceed 100 strokes per minute (spm). Pump, motor and driving arrangement shall be mounted on a robust combined baseplate.

Pump liquid ends shall be selected for compatibility with the pumped liquid. Suction and discharge valves shall be the single ball type allowing a free flow self-cleaning action. Ball and seat materials shall be resistant to abrasion. Strainers shall be provided with each pump.

Pumps shall incorporate a variable stroke mechanism to allow the output to be varied while the pump is running. Stroke adjustment shall be manual or where specified by electrical or pneumatically controlled stroke positioner. A stroke length indicator and digital stroke counter shall be fitted. Pumps shall be driven by a flange mounted IP 55 motor, via an oil bath reduction gearbox and variable stroke mechanism giving stepless adjustment between zero and maximum stroke length. Where flow proportional dosing is required the variation of output shall be achieved by varying the speed of the pump motor and not the pump stroke length.

The normal operating range of dosing pump shall be not less than 6:1.

a. Mechanical Diaphragm rigidly coupled to the drive train. Single suction Pumps and discharge valves. Glandless. Accuracy: ± 3% of stoke.

b. Piston Diaphragm Pumps hydraulically operated by liquid displaced by a plunger and protected from excess pressure via a relief valve. Accuracy: ± 2% of stroke.

Materials shall be selected to suit the chemicals being pumped. Liquid ends shall be polypropylene, AISI 316 stainless steel, glass, or Hastelloy C. Diaphragm materials shall be butyl rubber, PTFE, or Hypalon and glands shall be PTFE or Neoprene.

Each pump shall be provided with inlet and outlet isolating valves and where necessary, with pressure relief and non-return valves. Dosing pumps shall be provided with back pressure loading valves and pulsation dampeners in the delivery lines depending on the downstream conditions.

A relief valve shall be incorporated in the delivery lines under conditions where the pump discharge pipe can be shut off or where pressure may rise to an excessive point. The relief valve shall be sized to handle the system pressure and to discharge maximum pump output freely, and shall be located in the discharge line between the pump and the first downstream isolating valve or in the case of dosing pumps the back pressure loading valve. Relief valves when used on pumps handling nonhazardous chemicals shall discharge the vented liquid to waste. When used on hazardous chemicals the valve outlet shall be piped back to the suction supply tank or bunded area. The open end of the return pipe shall be located where it is visible, so that any relief valve leakage/operation can be detected.

Pump transferring/dosing chemicals to systems under pressure shall incorporate a pressure gauge on the pump delivery. Air cocks shall be provided for release of air where necessary. Unless otherwise specified flushing connections shall be provided at each pump inlet and flushing shall be manual. When flushing, water shall be discharged either locally through a drain valve or to the point of application of the chemical. Facilities shall also be provided for flushing chemical pump suction and delivery manifolds and delivery lines to point of application.

Dosing pumps and motors shall preferably incorporate an integral reduction gearbox drive which shall be totally enclosed and oil bath lubricated. The gear box shall incorporate the cams for the diaphragm drive and shall be provided with filling and drain connections and visible oil level indication.

7.4.9 **Submittals**

The Contractor shall submit following documents:

(i) Certified shop and erection drawing.

(ii) Equipment Manufacturer shall submit electronic files of the proposed equipment in the capacity, size, and arrangement as indicated and specified.

(iii) Data regarding pump and motor characteristics and performance:

(iv) Prior to fabrication and testing, provide guaranteed performance curves based on actual shop tests of mechanically duplicate pumps, showing they meet indicated and specified requirements for head, capacity, motor kW, efficiency and NPSH.

(v) For units of same size and type, provide curves for a single unit only.

(vi) Provide catalog performance curves at maximum pump speed indicated and specified showing maximum and minimum impeller diameters and number of stages available.

(vii) Results of shop performance tests as specified.

(viii) Submit curves for guaranteed performance, and shop performance tests on A4 sheets one curve per sheet.

(ix) Shop drawing data for accessory items.

(x) Certified setting plans, with tolerances, for anchor bolts.

(xi) Manufacturer's literature as needed to supplement certified data.

(xii) Operation and Maintenance instructions and parts lists

(xiii) Listing of reference installation as specified with contact names & details.

(xiv) Certified results of hydrostatic testing.

(xv) Certified results of dynamic balancing.

(xvi) Bearing temperature operating range for the service condition specified.

(xvii) Shop and field inspection reports.

(xviii) Shop and field testing procedures and equipment to be used.

(xix) Provide a scaled drawing showing the pumps, motors and hoist including equipment weights, lifting attachments and clearance for equipment removal and maintenance together with the location of discharge pressure gauges.

(xx) Manufacturer's product data and specifications for painting.

(xxi) The latest ISO 9001 certification.

(xxii) Material Certification:

- Provide certification from the equipment manufacturer that the material of construction specified and recommended and suitable for the service conditions specified and indicated.
- When material is not specified, technical data and certification that the proposed material are recommended and suitable for the service conditions.

7.4.10 **Pump Performance Guarantees**

The pump performance guarantee shall relate to the flow rate, the total head and the efficiency of the pump when tested at the manufacturer's works and shall obtain approval of Engineer.

The pump shall operate at its design point within acceptance tolerances for flow rate and total head laid down in BS: EN ISO 9906:2000.

Each pump shall be tested at the manufacturer's factory in accordance with IS 9137 or other relevant standards in conjunction with one of the contract motors.

This test shall be carried out on at least one pump set using the flexible coupling and contract drive shaft arrangement to establish that the drive arrangement with supports and couplings operates satisfactorily under all operating conditions.

Where similar drive shaft arrangements have been installed by the Contractor and have been proven satisfactory in service this requirement may be withdrawn subject to the approval of the Engineer.

A test shall be carried out of the performance from closed valve to the maximum quantity that can be delivered under abnormally low discharge heads.

Sufficient readings shall be taken at each test to produce accurate curves of the heads, flow, pump speed and power required at pump coupling throughout the operating range of the pump.

Vibration and noise dB(A) levels shall be measured and shown to be acceptable levels as per the contract and shall have Employer's Representative approval. The Contractor shall have Employer's Representative approval and provide acceptable test certificates, showing the NPSH requirement for the pump is at least 2 m less than the NPSH available under all working conditions.

Proto type pump shall be tested over the full operating range, covering from minus 70 percent of the bowl head to the shut-off head. The duration of tests shall be minimum one hour. A minimum of five readings shall be taken for plotting the performance curves. Hydrostatic pressure test shall be conducted for 30 minutes for all pressure parts. The test pressure shall be minimum 1.5 times the pump shut off pressure

The Contractor shall have Engineer's approval and provide acceptable test certificates, showing the NPSH requirement for the pump is at least 2 m less than the NPSH available under all working conditions.

In the absence of the approved test certificates the supplier shall carry out a test on one pump of each type to verify the NPSH requirement based upon the 3% output drop criterion and shall take approval of the Engineer.

Test Certificates in duplicate shall be submitted to the Engineer immediately following each of the tests mentioned above. Performance curves shall also be incorporated in the Operation and Maintenance Manual.

7.4.11 **Single/Parallel Pump Operation**

a) Head/quantity curve

b) Motor kW input/quantity curve

c) Overall efficiency/quantity curve

d) NPSH required/quantity curve

e) Vibration and Noise dB(A) levels

f) Head/quantity curves for parallel operation of pumps superimposed on system head curve.

7.5 Vacuum Gauges and Pressure Gauges

Pressure gauges shall not be less than 150 mm in diameter and shall be in conformance with specification detailed in Particular Instrumentation specifications Vol 2, Part 8 & 9.

Pressure gauge on delivery pipe and compound gauge on suction pipe of each horizontal centrifugal pump set of suitable range. Pressure gauge on delivery pipe of each vertical turbine pump set of suitable range. The gauges with dial size of 100 mm diameter complete with 3-way cock, isolation valve and connecting pipe.

The maximum range of the Pressure gauge shall be appropriately selected taking into considerations all operating pressures including water hammer encountered.

Vacuum gauge shall be calibrated in mm Hg.

Unless otherwise specified, scales shall be calibrated in meters head of water, with zero representing atmospheric pressure. The lettering shall be in black.

Compound gauges shall read at least 5 m below atmospheric pressure using red lettering.

Where the working fluid is of a corrosive or dirty nature the pressure gauge shall be protected from the working fluid by a diaphragm or similar arrangement.

Each pressure gauge shall be fitted with a stopcock immediately adjacent to the gauge and all pressure gauge piping shall be fitted with an isolating valve at the point of connection to the main system. Where pressure gauges are mounted within or on a panel a suitable connection for a test gauge shall be provided.

7.6 Air Compressors and Blowers

7.6.1 Air Compressors

The operation of all valves and instruments will be done electrically. However, if a compressor system is required, it shall comprise compressors, after-coolers and refrigerant type air dryer, duty/standby air receivers together with control equipment, oil eliminating filters, flow regulators and oil mist lubricators and auto drain units as required.

Type of air compressor shall be reciprocating type.

Electrically driven air compressor sets shall operate up to minimum 10 bar working pressure. Working pressure and capacity shall be adequate for the required duties.

Compressor sets with at least 1 standby shall be provided complete with the following:

a) Common base frame for Compressor & Motor
b) Single stage air-cooled unit
c) Isolating valves

d) Air filter and silencer
e) Pressure relief valve or excess pressure safety device
f) Pressure reducing valves
g) Pressure gauges
h) Pressure switches
i) Offloading piston
j) Automatic changeover (failure of duty unit)
k) Drain pipes
l) Isolating valve
m) V-belt drive arrangement with Belt Guard
n) Stoppers
o) Air-receivers
p) Air dryer (refrigerant type with auto drain.
q) Others necessary appurtenances

Compressors shall be arranged for automatic changeover on failure of the duty unit. Failure of the duty unit shall initiate an alarm. Control equipment shall include automatic unloading valves, pressure switches for duty standby and alarm, and lockable changeover switches. 1 duty & 1 standby after coolers shall be provided. Water-cooled or air blast types will be considered. Air receivers shall be designed and fabricated in accordance with relevant approved standards, they shall be mounted vertically on steel feet so that sufficient space is allowed for each access to the whole outside surface. Receivers shall be provided with drain cocks piped to drain pressure gauges and relief and check valves.

Supply of all necessary electrical components, devices, equipment, control panels. Etc. together with cabling, earthing provisions, etc. shall be responsibility of the Contractor.

Interconnecting pipe work shall be arranged to avoid low points, which may trap water. Unavoidable low points shall be provided with drain cocks piped to waste.

Pipe hood shall be provided on the top of headstock to protect the spindle from damage, dirt, dust, water etc. The hood shall be made of transparent fracture resistant polycarbonate material. The hood shall have vent holes to prevent condensation. All pipe works shall be SS-316 L

7.6.2 **Air Blower for Backwash of Filter Beds**

Air blowers twin lobe root type shall be provided for washing filter beds of each stage conforming to specifications hereunder:

- Twin lobe type Root Air blower shall have capacity to wash one filter bed at required pressure. Speed of blower shall not exceed 1500 RPM (synchronous)
- The number of blowers shall be 1 (W) + 1 (S)
- The main body, side covers shall be manufactured from Graded Cast Iron as per I.S. 210 / FG – 260.
- The Rotors shall be of forged construction (with Integral Shafts) in Twin Lobe Compressors with EN-8 Shafts.
- All components shall be machined to accurate dimensions with extremely tight

tolerance with guaranteed interchangeability. The Castings of Casing and main Covers (Bearing Housing) shall be stress relieved after pre-machining for dimensional stability at elevated temperature.

- The Lobes of Rotors shall have uniform clearances between rotor to rotor in any position of two rotors. The profile shall ensure uniform clearances between casing and Lobes.
- Sealing of main chamber shall be with labyrinth seal.
- Air blower shall be oil lubricated for driving and non-driving end. Grease lubrication shall not be acceptable. Both sides of casings shall be oil filled. All bearings and gears shall be splash lubricated for increased life of bearings and gears.
- The Timing Gears shall be helical teeth, hardened and machined to ensure low noise level.
- The Gears as well as the bearings shall be oil lubricated on both sides (Driving and non-driving side) of the Blower.
- All the Blowers shall be individually tested as per IS-10431/ IS-5456 for capacity, pressure, power consumption, temperature rise, noise level and vibration level.
- Each Twin Lobe Blower shall be equipped with various accessories like Two Silencer (for Suction and Discharge), Suction Filters, Safety Valves, Non-Return Valves, Anti Vibration Pads, Flexible Bellows, Air pressure gauge with isolating valve for delivery side of air blower.
- Each air blower shall be driven with electrical motor as per specification detailed for the motor. The motor shall have at least 15 % margin over the power required.
- Both Air blower and Electric motor shall be installed on common base with rigid concrete foundation. Air blower shall be coupled with electric motor by love joy type couplings. Radial and axial alignment of Air blower and electric motor shall be perfect.
- The blowers shall be equipped with all piping, valves and automatic change over to start standby blower if duty blower fails to start.

7.6.2.1 *General Design Requirements*

The air blowers shall be of such design as to achieve energy efficient operation continuously over the range of design airflow rates at the discharge pressure that shall remain practically constant.

The sizing of the blower units shall ensure that the peak airflow demand can be met by one duty blower with one unit on stand-by (two duty and one 50% standby will also be considered). Each blower shall be fitted with a variable speed motor and be capable of operating between 80% and 110% of its nominal peak airflow demand.

The discharge pressure shall be calculated by the Contractor dependent on the final design layout of the aeration system and of the delivery manifold.

The blowers shall also be capable of supplying the design "mass flow" rate at maximum ambient inlet temperature of 50°C.

Each of the blowers shall be capable of operating without surge in parallel with the other duty blower at the maximum mass flow against designed maximum gauge pressure at the outlet pipe. The Contractor shall demonstrate this during testing and commissioning. Performance curves for the blower system shall be submitted. Standard certified factory test sheets showing the results of each test shall be supplied in triplicate to the Employer's Representative prior to delivery of the blowers. The blower unit shall be capable to operate at maximum duty for continuous operation. The blower motor shall not exceed a maximum speed of 1500 rpm and the blower shall not exceed the manufacturer's recommended maximum speed.

Each blower shall be fitted with an acoustic enclosure. The arrangement shall be such that all blowers are accessible for operation and maintenance and the installation of additional blowers in the future is possible.

The inlet air to the blower house shall be filtered to suit the blowers and aeration diffusers selected. Vacuum switch, pressure switch, oil level indicator and any other monitoring device shall be mounted outside the acoustic enclosure. Inlet and outlet pressure gauges shall be mounted outside the acoustic enclosure. Vibration absorbing mounting pads shall be used.

A blower removal system shall be provided so that any one blower can be removed as a single unit and loaded on to a truck. The blower building shall be acoustically designed to minimize both noise inside the building and noise breaking out of the building. The building ventilation system shall be designed to limit the temperature rise not more than 3° C above ambient temperature.

Filters and Silencers

The blowers shall receive filtered air individual replaceable filter elements suitable for the intended duty.

The filter elements shall be housed in an airtight housing which shall allow easy replacement of the filter elements. Replacement of elements shall be possible without the use of tools.

If the filter/silencer elements supplied are located out of doors a weatherproof cover shall protect the filter element from rain.

The filter unit shall be fitted with suitable vacuum gauges to indicate the suction pressure into each blower. The gauges shall be industrial Bourdon of Schaffer type gauges with a nominal diameter of 150 mm. The scale shall be suitably selected and shall include a red line to indicate the point at which the filter elements require renewal.

Each blower intake shall be fitted with a differential pressure switch, which shall indicate an alarm signal in the event of excessive pressure drop in the blower intake.

Flexible Connections

The blower discharge shall be fitted with an approved flexible sleeve with fixing clamps and a flanged outlet spigot for connection to site pipework. If the blower inlet is via a common plenum the inlet pipe shall be also fitted with a flexible connection.

Sleeves shall be manufactured from an approved non-metallic material suitable for the duty and location in which the blowers are to be installed.

Pressure Relief Valve

The pressure relief valve shall be sized and adjusted to allow the full flow of the blower to be discharged in the event of a blockage or valve closure in the downstream pipeline and without overloading the drive motor.

Each blower shall be fitted with a suitable pressure switch, which shall shut down the blower in the event of excessive discharge pressure. The pressure setting shall be lower than the set pressure of the pressure relief valves.

The pressure relief valve shall be installed at a height above 2m from the floor and away from blower suction point. The pressure relief valve shall be fitted with a silencer.

Non-Return Valves

A non-return valve shall be installed on the discharge pipework of each blower, upstream of the blower isolation valve.

Isolating Valves

Isolating valves shall be installed on the delivery pipework of the blowers, such that each blower and all associated pipework and valves upstream of the common distribution manifold can be dismantled without disruption to the normal operation of the plant

Temperature Measurement

Temperature sensor complete with gauge of an approved type shall be supplied for each main distribution pipework and for the blower room.

Piping Vibration

If the blower type selected produces a discharge flow with a pulsating characteristic, flow pulsation dampers shall be installed on the blower intake and discharge, as required, to eliminate excessive noise or vibration from this source.

7.6.2.2 *Blower Noise limits*

The blowers supplied under this Contract shall be quiet in operation. The Contractor shall guarantee that the total sound power noise emission for the aeration system shall be broad band and free from any tonal or intermittent components. Under any loading condition from no load to full rated, the blower supplied shall comply with the noise requirements.

7.6.2.3 *Positive Displacement Blower*

The air rotary positive displacement blowers (Roots type or equivalent) shall consist of lobed rotors rotating designed for continuous operation at the required pressures and flows. The blowers shall be controlled by variable speed drives. The bowers shall be able to operate over a speed range to deliver the range of airflow rates nominated above.

Rotors and shafts shall be of one-piece construction and shall be of forged steel or shall comprise cast iron rotors on steel shafts. The rotors shall have two or more lobes and shafts shall be geared together with timing gears so that the lobes do not make contact during operation.

Bearing housings and rotor shafts shall be fitted with suitable oil seals to exclude dirt and moisture and to prevent oil carryover into the discharge air. Where bearings are oil lubricated the housings shall be fitted with effective oil level indicators.

The blower and motor shall be mounted on a base frame incorporating an integral silencer, non-return valve, pressure relief valve, discharge connection with flexible joint and flexible mounting pads (vibration dampers shall be placed under blower mounts.

The complete assembly including drive motor and lubrication system shall be mounted and aligned on a substantial galvanised sub-frame. Heavy-duty anti-vibration mountings are to be located on the underside of the sub-frame.

7.6.2.4 *Materials of Constructions*

The materials of construction for the blowers shall be at least equal in quality to the following:

COMPONENT	MATERIAL
Casings	Cast Iron
Base plate	Steel, Galvanized
Rotor/impeller	SS316 or Manufacturer's std
Shaft	SS316 or Manufacturer's std
Nuts and Bolts	Stainless Steel 316

7.7 Pressure & Storage Vessels:

i) Design of all vertical atmospheric storage tanks containing water, acid, alkali and other chemicals shall conform to IS:803

ii) Atmospheric vertical storage tanks shall be fabricated of mild steel as per IS:2062-Tested quality. Plates shall be cold rolled through plate bending machine by several number of passes to true curvature and joined by welding.

iii) Design of all horizontal atmospheric storage tanks containing water, acid, alkali and other chemicals should generally conform to IS:2825 as regards fabrication and general construction.

iv) Atmospheric horizontal storage tanks and all pressure vessels shall be fabricated of ASME Code Section VIII. Conical or flat (with/without reinforcement) ends shall not be accepted.

v) Design of all pressure vessels shall conform to ASME Code Section VIII Design pressure should be the maximum expected pressure to which the vessels may be subjected plus 5% extra margin. Maximum expected pressure for vessels placed in the discharge line of pumps shall be based on the shut-off head of the pumps plus static head at pump suction.

vi) Design temperature of vessels shall be 10 deg C higher than the maximum temperature that any part of the vessel is likely to attain in course of operation.

vii) Block and bleed type arrangement shall be provided for storage tanks in hazardous area.

viii) All MS vessels without inside rubber lining (including vessels with inside painting only) shall have a corrosion allowance of 2 mm (minimum) on shell and dished ends. Suitable mill allowance shall also be considered for shell and dished ends. Thinning/scaling allowance of 2 mm (minimum) shall be considered for dished ends. The minimum plate thickness of either pressure vessel or atmospheric storage tank shall be 6 mm.

ix) Manholes shall be provided in all vessels for providing easy access into the same. The size shall be minimum 500 mm and it will be provided with cover plate, nuts, bolts and gaskets to ensure leak tightness at the test pressure.

x) Adequate supporting arrangements like straps, saddles, skirt boards, pillars etc. shall be provided to transfer all loads to civil foundation. All foundation bolts, inserts etc. will also be included.

xi) All vessels shall be provided with lifting lugs, eye bolts etc. for effective handling during erection.

xii) Suitable seal shall be provided with the vent line of atmospheric tanks containing fuming liquids and also to prevent contamination from atmospheric air.

7.8 Sluice Gates and Electric Actuator

7.8.1 Sluice Gates

a) **Design Requirements and Construction Features:** The construction of sluice gates shall be in accordance with the specification and generally as per AWWA C 560-00 /IS:13349-1992 or other applicable standard. All sluice gates shall be thimble mounted and of the rising spindle type.

b) **Frame:** The frame shall be of the flange back type and shall be machined on the rear face to bolt directly to the machined face of the wall thimble.

c) **Seating Faces:** Seating faces shall be made of full width, solid section; dove-tail strips of stainless steel. They shall be secured firmly by means of counter sunk fixings in finished dove-tail grooves in the frame and slide faces in such a way as to ensure that they will remain permanently in place, free from distortion and loosening during the life of the sluice gates.

d) **Wedging Devices:** Sluice gates shall be equipped with adjustable side, top and bottom wedging devices as required to provide contact between the slide and frame facing when the gate is in closed position.

e) Lifting Mechanisms

- Sluice gate shall be operated through suitable lifting mechanism which shall incorporate suitable gearing if required, to keep the torque requirement within 7 kg.m.
- Lifting mechanism shall incorporate a strong locking device suitable for use with a padlock or padlock and chain.
- Lift mechanism shall be provided with a suitable position indicator to show the position of the gate at all times.

f) **Wall Thimbles:** The cross section of the thimble shall have the shape of the letter 'F'.

g) **Lifting Lugs:** Lifting lugs shall be provided for all gates.

h) **Flush Bottom Seal:** When sluice gates are provided with flush bottom seals, the wedging device and facing along the bottom edge of the slide and frame shall be omitted. A solid square cornered, resilient rubber seal shall be provided on the bottom facing of slide. The seal shall be securely fastened to the bottom face of the slide by a retainer bar and corrosion resistant metal fasteners. The top surface of the bottom facing of frame shall be flush with invert of the gate opening. Bottom facing of the slide shall be accurately machined to make contact with the seal when the slide is closed.

i) Suitable arrangement shall be made on all the sluice gates and actuators such that the actuator is capable of operating specific size of sluice gate, under this contract.

j) Headstock meant for mounting on operating platform shall be supplied with a pedestal/floor stand to provide a convenient operating height of approximately 900mm.The pedestal of the headstock shall be provided with a covered window opening to enable cleaning and greasing of stem threads.

k) All the Gears in the headstock shall be kept completely encased in cast iron housing to protect them from dirt. Dust, damage etc. and other atmospheric effects and thus ensure smooth operation. Grease nipples shall be provided at proper places for lubricating with grease.

l) Pipe hood shall be provided on the top of headstock to protect the spindle from damage, dirt, dust, water etc. The hood shall be made of transparent fracture resistant polycarbonate material. The hood shall have vent holes to prevent condensation.

m) The material of construction of sluice Gate shall be as follows:

Component	Material
Wall Thimble	Cast Iron : IS:210 Gr. FG 200
Frame and Slide	Cast Iron : IS:210 Gr. FG 200
Seating faces	Stainless Steel : ASTM Countersunk fixing A276 type 316
Wedge	Stainless Steel : ASTM A743 CF8M or SS316

Component	Material
Stem	Stainless Steel: ASTM extension A276 type 316
Stem guide bracket	Cast Iron : IS:210 Gr. FG 200
Stem nut	Stainless Steel : ASTM A743 CF8M
Stem Coupling	Stainless Steel : ASTM A276 type 316
Fasteners, anchor	Stainless Steel : ASTM A276 type 316
Lifting mechanism, Pedestal gear house cover and stem guide	Cast Iron : IS:210 Grade FG 200
Lift nut	Bronze : ASTM B 148 (CA952, CA954 or CA958)
Headstock Body	Cast Iron : IS:210 Gr. FG 200

7.8.2 Electric Actuator

Electric actuator for closing and opening of each sluice gate shall be provided as per the process requirement mentioned elsewhere in this document, so that the closing and opening operation time shall be maximum of 10 minutes. The local control shall be protected by a Lockable cover.

The Actuator shall be adequately sized to operate all the penstocks and be continuously rated to suit the modulating control required. The gear box shall be oil or grease filled, and capable of installation in any position. All operating spindles, gears and headstocks shall be provided with adequate points for lubrication.

The Actuator shall be capable of producing not less than one and half times the required torque and shall be suitable for at least 15 minutes continuous operation.

The Actuator starter shall be integrally housed with the Actuator in robustly constructed and totally enclosed weatherproof housing. The motor starter shall be capable of starting the motor under the most severe conditions.

The starter housing shall be fitted with contacts and terminals for power supply, remote control and remote positional indication.

Each starter shall be equipped as follows:

a) Three phase magnetically operated line contactors with no-volt release and electrical and mechanical interlock.

b) Three phase thermal cut-out device.

c) Control circuit transformer fully protected by fuses on primary and secondary circuits.

d) "Open", "Close" and "Stop" push buttons.

e) Local-off-Remote switch with padlocking facilities.

f) Torque and Limit switches for "open" and "Close" positions.

g) Auxiliary limit switches in each direction.

h) Gate position indicator and Handwheel for Manual operation.

i) Reduction Gear unit.

7.9 Valves

7.9.1 General

a) Valves shall be as per internationally recognized standards. Flanges shall be machined on faces and edges and drilled to applicable IS.

b) Valves shall be double flanged and the face shall be parallel to each other and flange face should be at right angles to the valve centerline. Backside of valve flanges shall be machined or spot faced for proper seating of the head and nut. Valve buried or installed in underground chamber, where access to a hand wheel would be impractical, shall be operated by means of extension spindle and/or keys. Valve shall be suitable for frequent operation as well as operation after long periods of idleness in either open or closed position.

c) The valve stem, thrust washers, screws, nuts and all other components exposed to the potable water shall be of a corrosion resistant grade of stainless steel 316/316L as needed. The valves in contract with sea water and /or brine shall be of nickel aluminum bronzes, or 9010 Cu-Ni with 1.5% Chromium alloys. Both these alloys are characterized by good resistance to static seawater (necessary for shut-down conditions) and to flowing seawater. Valves shall be free from sharp projections. Butterfly and non-return valves shall be provided with bypass arrangement having rising spindle gate valves. Bypass may be integral with valve or connected between pipes. A positive seal between the lining and the stem is provided to prevent access of seawater to the cast iron body.

d) The work of fixing appurtenances, i.e. butterfly valves, sluice valves, air valves, scour valves, etc. shall be carried out carefully so as not to damage them during handling, erection and fixing.

e) All the butterfly valves and sluice valves for pumping plants and isolation valves on pumping main (except scour valves on pumping main and the isolation valves for air valves) shall be electrically operated. The valves shall have arrangement for manual operation also, operated through a suitable gearbox, by hand wheel. Valves for operation shall be so geared that under the operating conditions as specified herein, the maximum force on the rim of the hand wheel, crank, or other necessary for operation shall not exceed 10 kg and the maximum torque shall not exceed 5.5 kg/m. Operation must be possible by one man against maximum design working pressure. For butterfly valves the gearbox shall be provided with self locking devices. A locking facility shall be provided for the BF valve in either the fully open, fully closed or intermediate position. Gate valves and butterfly valves shall be provided with position indicators, to show whether the valve is in the open or close position.

f) Scour valves shall be provided with extension spindle with supports for operation from operating level / ground level.

g) Gaskets shall be of NBR/Nitrile based rubber and ready-made matching with respective flanges. Gaskets cut out from rubber sheets are not acceptable.

7.9.2 **Butterfly Valves**

Butterfly valves shall be of double eccentric and resilient seated type generally as per IS:13095 and ASME B16.5 and should be tested as per ISO 5208-EN 1074.

Butterfly valves shall be suitable for bi-directional pressure testing with dead-tight shut off even after long period of operation of 5 years. The valves shall be of double flanged long type.

The valves shall be electrically/pneumatically and manual operated to suit the process requirement mentioned elsewhere in this tender document. The valve shall be free from induced vibrations. Valve shall be suitable for mounting in any position.

The valve seat shall be of replaceable design. When the valve is fully closed, the seal shall seat firmly. The seat surfaces shall be machined smooth to provide a long life for the seal. All fasteners shall be set flush so as to offer the least resistance possible to the flow through the valve.

The shaft shall be stainless steel with Bronze or equivalent seal with self-lubricating bearings. Disc pins shall be stainless steel 316L. For seawater/brine, the shaft shall be of super duplex steel and disk pin be of Duplex/ Monel K 500 / Inconel 625 as applicable. Rings shall be bi-directional self-adjusting suitable for pressure or vacuum service. Removal and replacement of seals shall be possible without removing the operating mechanism, valve shaft and without removing the valve from the pipeline. Valve shafts shall be a one-piece unit extending completely through the valve disc, or of the "stub shaft" type, which comprises two separate shafts inserted into the valve disc hubs.

All valve spindles and hand wheels shall be positioned to give good access for operational personnel. Valve of diameter 450 mm and above shall be provided with enclosed gear arrangement for ease of operation. The gear box shall be of worm and worm wheel design type, totally enclosed, grease filled and weather proof. The operation gear shall be such that they can be opened and closed by one man against an unbalanced head of 1.15 times the specified rating. Valve and gearing shall be such as to permit manual operation in a reasonable time and not exceed a required rim pull of 200 N. All hand wheels shall be arranged to turn in a clockwise direction to close the valve, the direction of rotation for opening and closing being indicated on the hand wheels.

Material of construction of valves shall comply with following requirement:

Item	For potable water application	For seawater application
Body	Cast Iron IS:210 Gr FG 220	DI with Ebonite lining / Cast 70-30 Cu-Ni/ 254 SMO
Disc	Cast Iron IS:210 Gr FG 220	ASTM A 890 Grade 5A

		(PREN>41)
Shaft	SS BS:970 Grade 431 S 29	254 SMO/ Super duplex steel
Body Seat	Nickel weld overlay micro finished	Manufacturer spec
Seal	NBR/EPDM	NBR/EPDM
Seal Retaining ring	Stainless steel AISI 316	254 SMO/ manufacturer spec
Shaft Bearing	Bronze with EPDM 'O' ring seals	Manufacturer spec
Internal Fasteners	Stainless steel AISI 316	Duplex SS/ Monel K 500 / Inconel 625
Nuts, bolts & washers for pipe flanges	Stainless steel AISI 316/316L	Stainless steel AISI 316/316L

The disc shall be designed to withstand the maximum pressure differential across the valve in either direction of flow. The disc shall be contoured to ensure the lowest possible resistance to flow and shall be suitable for throttling operation.

Valves shall be capable of closing against the maximum flow that can occur in system. The shaft shall be designed to withstand the maximum torque that will be imposed by the operator. It shall be secured to the discs by tapered stainless steel cotter pins.

Valves shall be provided with position indicator to show the position of the disc, mounted on the driven shaft end.

Rigid adjustable stop mechanism shall be provided within the gear box or elsewhere on the valve to prevent movement of the disc beyond the fully open or closed position (i.e. set points).

7.9.3 **Sluice Valves**

Sluice valve shall generally confirm to IS:14846 and as per ASME B16.5. They shall be of non-rising spindle type except for the valves for bypass. The gate face rings shall be securely pegged over the full circumference. Valve of 400 mm and above shall be furnished with a bushing arrangement for replacement of packing without leakage. They shall also have renewable channel and shoe linings. The gap between the shoe and channel shall be limited to 1.5 mm. Valve of 200 mm and above shall be provided with thrust bearing arrangement for ease of operation.

Valve of diameter 400 mm and above shall be provided with enclosed gear arrangement for ease of operation. The operation gear of all valves shall be such that they can be opened and closed by one man against an unbalanced head 15% in excess of the maximum specified rating. Valve and any gearing shall be such as to permit manual operation in a reasonable time and not exceed a required rim pull of 200 N.

Valves spindles and hand wheels shall be positioned to give good access for operational personnel. Hand wheels shall be arranged to turn in a clockwise direction to close the valve, the direction of rotation for opening and closing being indicated on the hand wheels.

Valves shall have two position marked at the shut end of the scale, first one corresponding to the position of the gate tangential to the bore of the seating and the second position below the first, corresponding to the position of the gate as it sits on the seating after moving a further distance equal to the depth of the seating.

All valves on pump suction and delivery piping shall be with electrical actuators. Operation of valves shall be with electric actuators mounted on floor stand at motor floor. The remaining sluice valves shall be manually operated unless specified elsewhere in this tender document.

Suitable arrangement shall be made on all the sluice gates and actuators such that the actuator is capable of operating specific size of sluice gate, under this contract.

Headstock meant for mounting on operating platform shall be supplied with a pedestal/floor stand to provide a convenient operating height of approximately 900mm.The pedestal of the headstock shall be provided with a covered window opening to enable cleaning and greasing of stem threads.

All the Gears in the headstock shall be kept completely encased in cast iron housing with suitable coating to protect them from dirt. Dust, damage etc. and other atmospheric effects and thus ensure smooth operation. Grease nipples shall be provided at proper places for lubricating with grease.

All Sluice valves shall be open end tested.

Bypasses for valves 400 mm and over shall be fitted with integral bypasses as per diameter in IS: 14846.

Material of construction shall comply with the requirements given below:

Item	For potable water application	For seawater application
Body, Door, Dome, Bonnet	Cast Iron IS:210 Grade FG220	Cast 70-30 Cu-Ni/ 254 SMO/ ASTM A 890 Grade 5A
Wedge	Cast Iron IS:210 Grade FG220 Rubber lined with EPDM	ASTM A 890 Grade 5A (PREN>41) / manufacturer spec
Seat, Face ring	IS:318 Gr. LTB 2	254 SMO/ Monel K 500/ Cast 70-30 Cu-Ni
Spindle / Stem	SS: IS:6603 04 Cr17 Ni12 Mo2 / AISI 316L	254 SMO/ Monel K 500
Bonnet Gasket	NBR/EPDM	NBR/EPDM
Internal Fasteners	Stainless steel SS316L	Duplex SS/ Monel K 500 / Inconel 625
Nuts, bolts & washers for pipe flanges	High tensile steel Hot dip galvanized	Stainless steel AISI 316/316L

7.9.4 **Plug Valves**

This Specification covers the minimum requirements for design, manufacture and supply of plug valves of size DN 50 mm (2 inch) and above and ANSI Class 150# thru 600#.

All valves shall be manufactured and supplied in accordance with the American Petroleum Institute (API) Specification 6D, Twenty Second Edition, 2002 including supplement 1 & 2 thereof with additions and modifications as indicated in the following sections of this specification.

The ASME Boiler & Pressure Vessel Code, Section VIII, Division 1 shall be used to design the valve body. Allowable stress requirements shall comply the provisions of ASME B31.3. However, the minimum valve thickness shall not be less than the minimum requirement of ASME B16.34. The manufacturer should have valid license to use API monogram on valves manufactured as per API 6D.

Valves shall be provided with plug position indicator and stops of rugged construction at the fully open and fully closed positions. Valves shall have locking devices to lock the valve either in full open (LO) or full close (LC) position. Locking devices shall be permanently attached to the valve operator and shall not interfere with operation of the valve

Reference has also been made in this specification to the latest edition of the following Codes, Standards and Specifications.

ASME B3 1.3 - Process Piping.

ASME B 16.5 - Pipe Flanges and Flanged Fittings.

ASME B 16.25- Butt-welding Ends

ASME B 16.34- Valves - Flanged, Threaded and Welding Ends.

ASME B16.47 - Large Diameter Steel Flanges.

API 1104 - Welding Pipelines and Related Facilities.

ASME Sec IX - Boiler and Pressure Vessel Code.

ASTM A 370 - Test Methods and Definitions for Mechanical Testing of Steel Products.

MSS-SP-6 - Standard Finishes for Contact Faces of Pipe Flanges and Connecting-end Flanges of Valves and Fittings.

MSS-SP-44 - Steel Pipe Line Flanges.

V SSPC-VIS-I - Steel Structures Painting Council Visual Standard.

Design Characteristics

Fluid	: Sea water
Diameter	: According to service
Design pressure	: ANSI 600 Ib
Connections	: BW Sch 40S - flanged

MATERIALS

Body and stem : Super Duplex ASTM A-890 Gr 5A
Joint : PTFE

7.9.5 **Non-Return Valves**

a) The valve shall be suitable for mounting on a horizontal pipeline and flow direction shall be clearly embossed on the valve body.

b) Valves shall possess high speed closing characteristics and be designed for minimum slam condition when closing.

c) Dual plate check valves shall conform to API 594 and API 598 (dimensions) and ASME B16.5 (connections). They shall have metal to metal sealing. The spring action shall optimize the equal closing rates of each plate especially when the friction coefficients are uneven due to one plate resting upon one another. The plates shall not drag on the seat while opening. The plates shall not vibrate under full or partial flow condition. Valves shall possess high speed closing characteristics and be designed for minimum slam condition when closing.

d) The minimum body-wall thickness shall conform to those given in Table 1B of API Standard 594. For low pressure piping, Class 150# and for high pressure piping Class 600# shall be used.

e) The face-to-face dimensions of valves (including valves with ring-joint facings) shall conform to those mentioned in Table 2B of API Standard 594.

f) The valve body shall be furnished with a clearly visible forged, machined-in, or die-stamped arrow to indicate the direction of flow through the valve.

g) Maximum permissible seat leakage is 7cc/Hr/cm nominal diameter of valve.

h) Material of construction of valves shall comply with IS code and as follows for seawater application.

Rating	Class#150/600 for low/high Pressure piping	Chemical feed piping
Body	ASTM, A 890 5A with PERN>41	ASTM, A 216 WCB and shall be internally lined with thick rubber/PTFE
Plate	ASTM, A 890 5A with PERN>41	ASTM, A 351 Gr CF8M
Hinge & Stop Pin	Inconel 625	SS. AISI 316
Springs	Inconel 625	SS. ASTM A 313
Seat	ASTM, A 890 5A with PERN>41	SS AISI 316
Retainer	Inconel 625	Carbon Steel
End Connection	RF, 150# as per ANSI B 16.5/ for 600# Grooved	RF, 150#as per ANSI B 16.5

Tag/Name plate	316 Stainless Steel (Engraved)	316 Stainless Steel (Engraved)

7.9.6 Air Valve

The air valve shall be double orifice kinetic type and conform to IS 14845. The valve shall be capable of exhausting air from pipework automatically when being filled, the air being released at a sufficiently high rate to prevent the restriction of the inflow rate. Similarly, the valve shall be capable of ventilating pipework automatically when being emptied, the air inflow rate being sufficiently high to prevent the development of a vacuum in the pipelines. The valve shall also automatically release air accumulating in pipework during normal working conditions.

Air valves shall thus be designed to automatically operate so that they shall:

- positively open under internal pressure less than atmospheric pressure to admit air in bulk during pipeline draining operation
- exhaust air in bulk and positively close as water, under low head, fills the body of the valve during filling operation
- not blow shut under high velocity air discharge
- exhaust accumulated air under pressure while the pipe is flowing full of water

All air valves shall be constructed so that internal working parts which may become necessary for repairs shall be readily accessible, removable, and replaceable without use of special tools and removing the valve from the line.

Air valves shall be of single chamber double orifice type and tamper proof unless otherwise directed by the Engineer. A buoyant rigid float shall seal the large orifice and the chamber housing shall be designed to avoid premature closing of the valve by the air whilst being discharged. Small orifice shall discharge small air volume during operation under full internal pressures. All air valves shall be provided with isolating sluice valve and flanged end connection.

The aperture of valves must be properly designed for which the Contractor shall submit design calculations for necessary approvals before the procurement of valves.

All branched outlets including air valve tees shall be provided with one ½" BSP coupling duly plugged for measurement of pressure in due course. The closing plug shall be in Stainless Steel (AISI 304 or equivalent) with Hex. Head and shall be provided with copper washer for sealing.

Material of construction of air valve shall comply with following requirement.

Body, Bonnet and cover	SG Iron 1865 Gr 400/12 or Grade GGG 40
Float	Polycarbonate up to 50 NB and SS 316 Ti/ AISI 316 Ti for above 50 NB
Internal Linkages	Stainless Steel 316L

Seat Ring	Dexine (Nitrile Rubber) on Bronze seat
Gasket / Seal	EPDM/NBR
Shut off Device	Stainless Steel (ASTM A240 Grade 321/AISI 321)

Bidders are encouraged to submit alternative design. Alternative design of air valve is subjected to approval by the Engineer.

7.9.7 Pressure Relief Valve

a) Pressure relief valves shall be capable of relieving pressure in the system to prevent the system being pressurised in excess of a preset maximum allowable pressure. The valves shall be drop tight under normal operating conditions.

b) The valve operation shall be achieved by the interaction of the inlet pressure and an intermediate pressure produced by a pilot valve or relay system acting on the upper side of the main valves.

c) The pilot valve or relay system shall be actuated by a diaphragm connected to the inlet pressure on its underside and a constant pressure on its upper side derived either from weight or from a spring.

7.9.8 Pressure Reducing Valves

a) Pressure reducing valves shall be capable of maintaining a constant downstream pressure from a higher constant or variable upstream pressure and they shall be drop tight under no flow conditions.

b) The valve operation shall be achieved by the interaction of the inlet pressure, outlet pressure and an intermediate pressure produced by a pilot valve or relay system acting on the upper side of the main valve.

c) The pilot valve or relay system shall be actuated by a diaphragm connected to the outlet pressure on its underside and a constant pressure on its upper side derived either from weights or from a spring.

d) Body ends shall be flanged and drilled to applicable IS.

The materials for the valves shall be as follows or better as per application:

a) Cast iron body and cover.

b) Internal valve, gunmetal with bronze liner, cups and facing rings in leather.

c) Relay valve, bronze with stainless steel spindle and nylon valve face.

d) Diaphragm reinforced synthetic rubber.

e) Loading spring, if employed - spring steel.

f) Tonner and weights, if employed - cast iron.

g) Lever, steel with gunmetal pins and links.

h) Connecting pipe work to tonner - copper.

i) Tonner, mild steel epoxy lined with internal working parts gunmetal bushed.

7.9.9 **Diaphragm Valves**

Diaphragm valves shall be of the full-bore type to suit the maximum working pressure ratings required. Body ends shall be flanged and drilled to applicable IS or BS EN 1092-2.

Indicators shall be supplied where specified showing both OPEN and CLOSED positions shall be supplied and provisions made for initiating the operation of remote indicator lights in the fully OPEN and CLOSED positions.

Valves used for toxic or hazardous fluids shall be provided with an additional `O' ring seal of nitrite rubber or other approved material.

Diaphragms shall be composed of moulded reinforced, flexible material attached by studs to the compressor. Diaphragm materials shall, where required, be composed of corrosion resistant material.

7.9.10 **Isolating Cocks**

For isolation of small bore pipework tapings for instrumentation equipment etc., and for individual component isolation, the cocks shall be stainless steel, 0.25 turn ball or plug valve with the operating handle arranged to indicate the open and closed positions. Where specified, means shall be provided for securing the valve body to a front panel or near surface.

7.9.11 **Valve Actuators**

Control actuators for fan dampers, control valves and miscellaneous modulating dampers can be electrical, pneumatic, hydraulic or hybrid, depending upon application requirement. For high torque/high thrust applications, electro-pneumatic/electro hydraulic actuators are used.

All control actuators shall have stalled torque rating of at least 150 per cent of the maximum required torque for the driven element.

7.9.11.1 *Electric Actuators*

The sluice valve on pump suction and discharge lines and butterfly valve on pump discharge line and pumping main shall be operated by electric actuator and the operating mechanism shall consist of the following accessories:

a) AC Electric Motor.

b) Reduction gear unit.

c) Torque switch mechanism

d) Limit switch mechanism complete with set of limit switches and additional two spare sets for open/close position.

e) Hand wheel, for manual operation.

f) Valve position indicator.

g) Hand-auto lever with suitable locking arrangement.

h) Single phase space heater in the switch compartment

i) Indication throughout the valve operation.

j) Junction box for terminating power and control cables.

The actuator shall be suitable for operation on 415V, 3 phase, 50 Hz power supply in the climatic conditions given in the Specification. The motor winding insulation shall conform to Class B as per relevant BS and motor shall be protected by suitable thermal overload relays. The actuator shall be capable of producing not less than 1.5 times the required torque at the required time cycle of valve operation. The transmission shaft connecting the actuator to the valve shall be provided with 2 bearings one at actuator end and one at valve end with universal couplings at suitable places. Adequate no. of switch/contacts shall be provided to meet following requirements.

Valve close/open/in operation indications:

a) To prevent starting of motor if discharge valve is not fully closed.

b) To trip the motor, if the discharge valve fails to open within specified time.

Each motor shall be suitable for operation in the site climatic conditions. They shall also be suitable for operating on the specified electric supply and shall satisfactorily open and close the valve under variations of electric supply specified.

The electric motors shall be of the squirrel cage type as per IS: 325 with insulation to IS: 1271 Class The windings shall be impregnated to render them non-hygroscopic and oil resistant. All internal metal parts shall be painted. The motor shall be rated for 15 minutes.

Motor shall be protected by suitable overload protection device.

The reversing contactor starter and local controls shall be integral with the valve actuator. The starter shall comprise mechanically and electrically interlocked reversing contactors of appropriate rating transformer. The common connection of the contactor coils at the transformer shall be grounded. HRC cartridge type primary and secondary fuses shall be provided.

Local control shall comprise pushbuttons for open, close and stop operations and a Lockable Local/Remote/off selector switch. The control schematics shall be subject to approval.

Internal wiring shall be of 650/1100 volt grade PVC insulated stranded copper conductor of minimum 1.5 sq. mm for control circuits and of minimum 4 sq.mm copper for the power circuit. Each wire shall be number identified at each end. The terminals shall be of stud type. Cable entries shall be suitable for PVC insulated/ sheathed, armoured cables. A separate terminal box shall be provided for the heater. A separate terminal box shall be provided for cabling to control circuits.

The actuator enclosure shall be fully weatherproof and hose proof to IP 67 and shall be fitted with an anti-condensation heater, which shall be switched off when the motor is running.

Reduction Gear Unit shall be of the totally enclosed oil bath lubricated type. The gear box shall be provided with the first charge of oil lubricants and appropriate filling and drain connections. Gearing shall be adequate to open and close the valves under full indicated maximum operating pressure differential at a speed sufficient to cover the full extent of travel.

The operator shall have a hammer-blow device to loosen stuck valve or retrieve jammed valve position.

The torque switch mechanism shall function as follows to stop the motor on closing or opening of the valve, or upon actuation by the torque when the valve disc is restricted in its attempt to open or close.

The torque switch in the closing direction shall interrupt the control circuit if mechanical overload occurs during the closing cycle or when the valve is fully closed.

The torque switch in the opening direction shall interrupt the control circuit if mechanical overload occurs during the opening cycle or when the valve is fully open. The mechanism shall facilitate adjustment of the torque at which the switches are required to operate.

Non-adjustable limit switches shall stop the motor and give indication when the disc has attained the fully open or closed position.

The adjustable limit switches shall have control rated 2A, 48 V DC for specified system interlock, at the desired value position in both the opening and closing directions.

Motor operators shall be provided with clearly visible local valve position indicators mounted on the operator assembly to give an indication whether the valve is fully open, fully closed or in an intermediate position.

A hand wheel of Stainless-Steel construction shall be provided for emergency operation. The hand wheel drive shall be mechanically independent of the motor drive and any gearing should be such as to permit emergency manual operation in a reasonable time.

7.9.11.2 *Pneumatic Actuators*

Pneumatic actuator shall operate the valve as per torque requirement of valve for the function and duty. Working temperature range: From - 20° to +80 °C.

Pneumatic actuators shall be provided complete with line filter, regulator, positioner when required, manual operating handle, solenoid valve and air lock system. Actuators shall be sized for shut-off differential pressure. All pneumatic valve positioners shall be supplied with local pressure gauges to indicate supply pressure, control pressure and feed-back pressure. SMART valve positioners (with HART or field bus compatible) shall be considered wherever required. All pneumatic control valves shall have facility for position feedback (4-20 mA) for transmission to control room. For spring-opposed diaphragm type actuators, the spring shall be corrosion resistant and cadmium or nickel-plated.

a) MOC
   - Body-Cast iron FG260
   - Fasteners-stainless steel
   - O rings/seals – BUNA-N (Nitrile)

- Tonner – Aluminum Alloy LM4 / LM6
- Shaft – Carbon steel

b) These actuators shall be pneumatically operated, travelling a minimum of 90° in each direction and be able to over travel at 3° more in each direction past 90°. Pneumatic actuator shall develop required torque to operate of valve

c) The Actuator shall be totally enclosed and contained in a single enclosure with no external moving part.

d) Air junction box shall be provided for opening and closing of valve. All pneumatic passage ways must be integral to the actuator housings.

e) Air junction box shall be having air control arrangement for inlet and outlet for connection of air inlet and outlet at least 10 mm dia size threaded connection arrangement shall be provided.

f) Pneumatic Actuator shall be designed for the automation of ¼ turn valves (butterfly valve,) with double acting pneumatic arrangement.

Valve positioners or boosters may be considered for actuators for the following applications:

- To split the controller output to more than one valve.
- To amplify the controller output beyond the standard signal range (i.e., 0.2- 1kg/cm2), in case of actuators with greater thrust or stiffness is required.
- To achieve minimum overshoot and fast recovery in control action, as in the case when long control air lines have to be used.
- In all the above applications, whether or not a positioner or booster is to be used, shall depend on the speed of response of the system.
- Wherever required, boosters shall be used for systems with a fast response (e.g. Pressure and flow control loops etc.) and positioners shall be used for relatively slower control loops (e.g., temperature and level loops etc.).
- Actuator casing and diaphragm shall be designed to withstand at least twice the maximum pneumatic operating pressure of the control valve.

7.9.12 **Control Valves Design**

Control valves for modulation service shall generally be pneumatically or electrically operated. Control valves shall be sized in accordance with ISA-S75-01. The noise level produced by any equipment like pump sets, compressor sets and blower sets etc. shall not exceed National Standards

Control valves shall be sized so that at minimum and maximum flow, the valve lift is always between 10% to 90% for equal% and 20% to 80% for linear characteristics.

Globe type control valves shall be, in general, used in throttling applications for valve applications up to 500 mm line size, when the line pressure is not very low & fluid is non-viscous.

Single seated globe valves with top guided plugs shall be generally used for low & medium flow applications & for clean fluid applications as well as fluid with suspended particle applications. Cascaded trim shall be used for cavitation services.

Globe valves with cage guided plugs are pressure balanced & shall be used for high flow applications where the fluid is clean or if there is a chance of flushing/cavitation. Generally, single seated globe valves with cage-guided plug shall be used from the viewpoint of maintenance & for better leakage class. However, double seated cage guided valves shall be used for better pressure balance, based on the process application.

Top & bottom guided double port double seated straight through type globe valves shall be used for very high flow applications & where wide range ability is required.

Wide range ability is possible, as the valve operation is quite steady throughout the stroke due to relatively low unbalanced force & because of the guiding at top & bottom. Another advantage of this type of valve is that valve action can be reversed without change of actuator.

Other types of valves (e.g. Butterfly, angle, eccentric-disk, ball, V-notch ball type, etc.) shall be used only when operating conditions do not allow globe type valves.

For high viscous liquids, V-notch ball valves shall be used.

Angle valves shall be used wherever piping layout so desires. It is devoid of dead pockets & possible to achieve fine control through it. It can be used in slurry application also. In case of high-pressure drop application, multistage single seated cage guided angle valves shall be used. In very high-pressure drop applications, the multi stage pressure reduction trim prevents the liquid pressure falling below the saturation pressure at vena contract, thereby eliminating the chance of cavitation. Due to its geometry, the chance of erosion & noise level is comparatively less than similarly constructed conventional globe type valves.

Three-way valve shall be used in mixing & diverting services

Butterfly valves may be used for modulating service but shall not be used for, shut-off service if the maximum differential pressure across the valve exceeds 3 kg/sq cm.

Concentric disc type/ eccentric disc type butterfly valves shall be used in large line sizes & mainly in low-pressure applications or where allowable pressure loss across the valve is very low. Concentric disc type butterfly valves shall be designed for maximum opening angle of 60°. The maximum permissible opening for eccentric disk type butterfly valves shall be 90°. Applications where wide range ability is required, eccentric disc type butterfly valve shall be used instead of concentric disc type butterfly valves.

Flange facing and drilling shall, be according to either Indian or similar other international flange standard.

Control valves of sizes 40 mm and above shall have flanged end connections.

In general control valves of sizes 25 mm and below shall have screwed connection except as follows:

i) Other types of end connections shall be used when required by piping specification.

ii) Stainless steel valve bodies shall have flanged connection for sizes 25 mm and larger.

Valves sizes shall be based on specified allowable pressure drop at 130 percent of normal process design flow conditions.

Valves shall be sized so that the valve will operate properly when upstream pressure is 10 per cent above maximum inlet pressure and downstream pressure is atmospheric.

Extended bonnets and high temperature packings shall be used for high temperature application. Extension-bonnets shall be provided in control valves for services above 200°C or below (-) 30°C, or as recommended by the manufacturer. Teflon asbestos packing shall be used up to 200oC temperature and graphite lubricated asbestos shall be used for operating temperature higher than 200oC.

Valve trim for most application shall be stainless steel for pressure drops of up to 7 kg/sq cm. For pressure drops above 7 kg/sq cm hard trim shall be used. Other alloys shall be substituted if required for corrosive conditions.

Minimum valve size shall be 25 mm for line size 25 mm and larger, using reducers, if necessary.

Hand-wheels, isolating valves and by-pass valves shall in general be provided for each control valve application. Isolating valves shall be of line size whereas by-pass valves shall be of control valve size.

For on-off control in small pipelines below 50 mm diameter, 2-way or 3-way solenoid valves shall be provided. Coil voltage shall be 24 V DC or 110/240 V AC rating and shall be suitable for continuous operation.

Control valves used in safety shut-off service shall be single seated tight shut-off valve. Leakage class of all fuel gas safety shut off valves shall be as per ANSI Class-VI. For other media, the shut off valves shall be of Class-V/Class-VI. Leakage class for control valves used for modulating action shall be as per ANSI Class IV.

Noise level of the control valves shall be as per accepted standard and shall be within 65 dBA from 1 meter of valve body.

Wherever required, line mounted Solenoid Valves may be used up to line size of 2 inch beyond which, pneumatic valve with internal pilot operated solenoid valves made of stainless steel shall be used.

Valve stem-position indicator shall be provided for all the control valves.

Solenoid valves installed in the control air supply line shall be of Universal type having minimum Class F insulation and shall be continuously rated direct-acting type. Solenoid valves shall be full-bore type with minimum bore size 3 mm.

7.9.13 **Support of Pipe Work and Valves**

Pipe work, valves and other connected equipment, or forming part of the operating system, shall be provided with adequate supports, brackets, thrust blocks and fixtures, as necessary and in an approved manner, to restrict any induced vibration to a minimum, under any operating condition.

Valves, meters, strainers and other devices mounted in the pipe work shall be supported independently of the pipes to which they connect. All brackets or other forms of support, which can conveniently be so designed, shall be rigidly built up of steel by welding in preference to the use of castings. No point of passage of pipes through floors or walls shall be used as a point of support. Vibration measurements shall be taken on site by the Contractor at various points on each complete machine as defined above. If any item is found to be vibrating

beyond the level considered by the Engineer to be a reasonable minimum, the Contractor shall reduce the vibrations to the required level as specified in the relevant standards.

7.10 Hand Railing

Hand - railing shall be double rail 1100 mm high measured vertically from the nose of the tread. All components for hand railing shall be SS-316 with cathodic protection.

7.11 Adjustable Weir Plates

The adjustable weir plates shall be manufactured from 316 stainless steel and the design shall have the approval of the Engineer.

Weir plates shall be complete with fixing nuts, bolts and washers and suitable for a total vertical adjustment of 100 mm. Fixings shall be designed for ease of accurately levelling the plates, securing the plates, and shall enable the plates to be adjusted during the life of the Works to accommodate differential settlement of the structure.

7.12 Mixers

All mixers supplied under this Contract shall be of a standard and proven design for which spare parts are readily available in India. The number, size and position (including depth and orientation) of mixers shall be designed to maintain a fully mixed homogeneous solution within the entire volume of the tank or zone being mixed. Solids shall remain in suspension in a homogenous mixture for each cell.

The design and arrangement of the mixer(s) shall be determined and verified by hydraulic and mixing performance modelling. All modelling and analysis shall be based on the specific mixer design proposed and all modelling results shall be submitted for approval. The performance modelling shall verify that the velocity profile across the entire floor area of the mixing tank/zone shall be sufficiently high so as to eliminate potential "dead-spots". The effectiveness of the installed mixers shall be such that the % w/vol solids at any single point within the tank or zone do not vary by more than ± 10%. The mixer shall be designed so as not to entrain air or promote surface vortices. The Contractor shall design the necessary features to prevent any ragging in the mixer impeller. The mixers and shall comply with the following requirements:

- The mixers shall provide continuous operation at their calculated design duty point. All calculations and drawings shall be submitted.
- The continuous rated output of the electric motor driving the pump and mixers shall be at least 10% in excess of the maximum power required by the unit under all operating conditions.

- Each submersible mixer and its motor shall withstand without damage to the mixer or any other equipment the effects of reverse rotation up to 120% of normal direction rated speed.

The Contractor shall purchase mixers and driving units from one source (the mixer manufacturer) to ensure the parts are compatible mechanically and electrically.

The materials of construction for mixers shall be of the following quality:

- Impeller SMO 254/Solid GRP
- Shaft construction SMO 254/Solid GRP
- Mechanical Seal Silicon carbide/silicon carbide
- Guide Bar with Brackets, Lockplates Stainless steel: AISI 316L
- Fasteners Monel K 500/Incoloy 625

7.12.1 **Submersible Mixers**

Each submersible mixer shall be supplied complete with the following:

- Mounting arrangement, complete with coupling devices, guide rails and support brackets;
- Swivel mechanism for rotation of the mixer in horizontal and vertical planes;
- Placement / Removal Apparatus, including swing type lifting davit, stainless steel grade 316L lifting cable, stainless steel winch and shackles,
- Composite power and control cable length;

The mixers shall be provided with adjustment for depth and mixing direction. Mixers shall include a motor and impeller; in a close-coupled configuration, forming a compact, and robust mixing unit. Four-pole motors are preferred to multi pole motors.

Appropriate shroud arrangements shall be provided where necessary to prevent air entrainment and vortices. The design of the casing and propeller shall allow an uninterrupted flow across the units, allowing the mixing media not to be caught and allowing cooling of the mixer.

The mixers shall be manufactured from stainless steel materials selected by the manufacturer to suit the duty requirements, fluids and operating conditions. The guide rail arrangement shall permit easy adjustment of the submersible mixer orientation in the vertical and horizontal planes, by an operator standing on the access platform.

Mixers shall be readily removable for inspection and maintenance using the lifting equipment, without the need for personnel to enter the tank. The lifting arrangement shall enable a single operator to easily lift each mixer from its installed location and place it on the access walkway/platform without removing the handrails. Similarly, a single operator shall be able to easily replace each mixer to its installed location. No portion of the mixer shall be permanently fixed to the base of the tank.

A stainless steel 316 lifting chain of sufficient length to reach from the mixer to the platform level shall be provided with each mixer. All holding down bolts shall be of 316 grade stainless steel. For lifting facilities by a davit, the mixer shall be fitted with stainless wire rope and brake winch.

Electrical cables for each mixer shall be suitably protected and supplied in place so as to prevent any damages.

The mixers shall have the following features:

- Can be used in every shape of tank.
- Self-cleaning & non-clogging propeller with Energy saving
- Hydrodynamic shape for optimum flow formation
- Drive unit optimised for mixing applications
- Little maintenance and long operating life.
- The mixer shall be driven by a high efficiency 3 phase motors IP68 Class F. Motor shaft and rotor shall be dynamically balanced.
- The mixers shall have the flexibility to be located at different depths and thereby avoiding dead zones.

The motor shaft shall be supported by two no's of single row double shielded anti-friction bearings with rating of life of minimum 100000 hours.

Scope of supply of each mixer shall include but not limited to Mixer with motor, Gear reducers, Seal monitoring relay, Moisture sensors, Guide mechanism complete with rope winch, power & control cable, chain, vibration dampeners and standard repair kit.

7.12.2 **Flash Mixers and Top Entry Mixers**

The mixers shall enter tanks vertically from the top and normally operate continuously.

The mixer shall be complete with mounting unit, reduction gearbox and motor. The design should be suitable for outdoor mounting and enclosure protection shall be provided to IP 55.

The mixer paddles and shafts shall be grade 316/316/L stainless steel. The shafts shall be sufficiently rigid to prevent flexing. Maximum deflection shall be limited to shaft length/1000. The shafts shall be fitted to the gearboxes in a positive manner, which may take the form of keyed flanges with retaining bolts or equivalent. Mixers can be supported near the blades.

7.12.3 **Online Static Mixers**

Online static mixer shall be provided as per the process requirement. The maximum pressure drop due to static mixers shall be restricted to 0.5 bar.

The materials of construction for mixers shall be of the following quality:

Impeller:	FRP/GRP
Body:	SMO 254/Super Duplex
Mechanical Seal:	Silicon carbide/silicon carbide
Fasteners:	Monel K 500/Incoloy 625

7.12.4 **Shaft Seals**

7.12.4.1 *General Requirements*

The Contractor shall provide all mixers with mechanical seals. The seals provided shall be capable of allowing the mixers to run. Two independent mechanical face seals assembled in tandem shall be fitted to provide reliable and durable sealing performance.

The seals shall be designed for a minimum operating life of 5 years under normal operating condition. Spare mechanical seals shall be supplied to the extent of the life of pumps. The seals shall be of the balanced type, cartridge mounted, incorporating bellows or multiple helical springs of stainless steel grade 316 and high nitrile synthetic rubber or ethylene propylene static "O" rings. Seal faces shall be lapped flat to within two (2) helium light bands and the depth of interface roughness shall not exceed 0.3 microns.

7.12.4.2 *Seal Failure Detection*

Submersible type pumps and mixers shall be fitted with seal failure probes for moisture and oil leakage. The probe shall be fitted in the oil bath between the two mechanical seals and shall be arranged to detect the presence of water in the oil bath, e.g. to detect failure of the propeller seals. A moisture detection device shall be fitted in the motor stator housing and cable termination housing. Sensors shall be compatible with Tritronics RT1 relay.

7.12.4.3 *Motor Protection*

All mixers shall be protected from overheating by a positive temperature coefficient (PTC) thermistor in each phase of each stator winding. Each thermistor shall be connected in series to terminals adjacent to the stator terminals and encapsulated and compatible with motor selected; or sensors shall be compatible with Tritronics RT1 relay.

7.13 Glass-Fused-to-Steel Bolted Tank

7.13.1 **Materials**

Plates and sheets used in the construction of the tank shell, optional floor and roofs, shall comply with the minimum standards of ISO 28765:2008 Section 9.2. Such sheets shall be produced by a hot rolling process and shall be sourced from reputable International steel mills.

Raw materials delivered to the Manufacturer's plant shall be tested / inspected to ensure compliance with the Manufacturer's requirements for strength.

Test Certificates issued and conducted by third party reputable international organization shall be available for the Engineers inspection if required. Such Certificates shall be requested before the time of issue of the Purchase Order.

7.13.2 **Horizontal Wind Stiffeners**

The top stiffener of the roof shall provide a flat, horizontal, continuous surface at tank rim level.

Wind stiffeners shall be steel, hot dipped galvanised, rolled steel angle bar.

7.13.3 **Bolt Fasteners**

Bolts used in tank lap joints shall conform to BS 3692 and shall be V2" - 13 UNC-2A rolled thread with hot dipped galvanised coating.

All bolts for tank shell and Glass-Fused-to-Steel roof (where applicable) shall be installed such that the head portion is located inside the tank and the washer and nut are on the exterior.

All lap joint bolts shall be properly selected such that threaded portions will not be excessively exposed in the "shear plane" between tank sheets. Also, bolt lengths shall be selected to achieve a neat and uniform appearance. The torque values (as set down in the Manufacturer s Construction Guide) shall not be exceeded during tank construction.

All lap joint bolts shall be designed to prevent rotation during tightening.

7.13.4 **Bolt Head Encapsulation**

All tank shell and Glass-Fused-to-Steel roof structure bolts shall have UV resistant polypropylene encapsulation of the bolt head and be certified to meet Regulation 31 or NSF Standard 61 for indirect additives.

All other bolts shall be hot deep galvanized conforming to BS 3692 and shall be Vz -13 UNC-2A rolled thread with hot dipped galvanised coating

7.13.5 **Sealant**

The sealant shall be used to seal lap joints, bolt connections and sheet edges. The sealant shall cure to a rubber-like consistency and have excellent adhesion to the glass coating, have low shrinkage, and be suitable for interior and exterior exposure. The sealant shall be a one component moisture cured polyurethane compound.

Where required, the sealant shall be suitable for contact with potable water and meet Regulation 31 or NSF Standard 61 where specified.

Bidder should submit Certification of conformity of the Manufactured to Regulation 31 or NSF Standard 61 issued by NSF to ensure compliance to the above section.

EPDM or Neoprene gaskets and tape type sealer shall not be used other than for shell manway door/hatch.

7.13.6 **Glass Coating**

In cases where both the inside and outside surfaces of the sheet are in contact with the stored liquid both surfaces shall be treated as the inside surface for the purposes of this specification.

Coating Standards

The tank coating shall meet the quality requirements of ISO 28765:2008 and should conform to NSF Standards.

Surface Preparation

Sheets shall be steel grit-blasted to a silver grey finish on both sides to remove mill scale and surface oxidation.

Grit blasting shall be performed to the equivalent of SA21/4 or SSPC-SP10.

The surface anchor pattern shall be in the range of 20um to 100um with a target value of 60um.

7.13.7 **Cleaning**

Immediately after fabrication and grit blasting and prior to application of the coating materials, all sheets shall be thoroughly cleaned by an alkali wash.

Following the alkali wash all sheets shall be rinsed in hot water containing a nitrite-based rust inhibitor.

The rust inhibition process shall be followed by heat drying to ensure the sheets are clean and dry ready to be coated.

7.13.8 **Coating**

All sheets shall receive a coat of catalytic nickel oxide-based pre-coat to both sides. The pre-coat application weight is controlled and measured and sheets that do not meet the required specification, in accordance with the Manufacturer's specified parameters, shall be rejected at this point.

All pre-coated sheets shall be heat dried to ensure that a moisture free surface has been achieved before the glass coating layer is applied.

A coat of cobalt rich glass slip shall be continuously applied to both sides of the sheet followed by heat drying.

The coated sheets shall be visually inspected and sheets with spray or glass defects shall be rejected at this point.

The thickness of the coating system shall be measured using an electronic instrument; the instrument shall have a valid calibration record. Interior and exterior dry film coating thicknesses are controlled and measured and sheets that do not meet the required specification, in accordance with the Manufacturer s specified parameters, shall be rejected at this point.

After inspection the sheets shall be fired through the furnace at approximately 850°C in accordance with the Manufacturer s procedures.

The firing process shall form a composite glass surface having general acid/alkali resistance to solutions in the range pH 3 to pH 9, subject to temperature and chemical composition.

Tank inside sheet colour shall be as specified by the Manufacturer. Tank external colour shall be Blue (20-C-40) or Green (12-B-29).

Sample tests shall be carried out by the Manufacturer to ensure that enamel materials meet the physical properties and chemical resistance characteristics as published in the Manufacturer's product Quality Standard. The Manufacturer shall provide published product Quality Standards detailing the International Standards used for testing.

Bidder should submit Manufacturer's Product Quality Standards detailing International Standards used for Manufacturing and Sheet Coating Procedure and Process.

7.14 Flocculation and Clarification

7.14.1 Flocculation

The flocculator shall be paddle type designed to achieve flow mixing in flocculation chamber to G ranging between 20^{-s} to 40^{-s}. The design shall be based on G value to be selected. Justification for G value selection shall be furnished. The electric motor shall be suitable for outdoor duty as per specification.

7.14.2 Clarification

Tube Settler process shall be provided.

Clarifier shall be single design for each work and shall be of concrete construction each with identical internal dimensions.

7.14.2.1 *Tube settler*

The media shall be in PVC construction, simple hexagonal configuration and robust. The tube module shall to be kept at inclination $55\text{-}60^0$ to horizontal. The media shall be supported on structural steel members in symmetrical manner.

7.14.2.2 *Sludge Draw-off*

The hopper shall be provided to collect the sludge in the hopper bottom under gravity. Sludge draw-off arrangement shall include the following:

- Sludge line of suitable diameter but not less than 200 mm from each hopper of the clarifier to common header
- Common header not less than 300 mm discharging into sludge balancing tank.
- The line from hopper to common header shall incorporate Tee and rising spindle type sluice valve with electrical actuator.
- All connections in common header and line shall be with flange joint and flange adaptor to facilitate dismantling to manually remove clogging in the pipe.
- Sampling and rodding point for jet cleaning of the sludge line shall be provided.
- Sluice valve shall be provided in the pipeline below each hopper with remote ON/OFF facility.
- In common header, a knife value shall be provided with ON/OFF facility.
- Sufficient valve shall be provided to make the cleaning of a hopper using water jet.

7.14.2.3 *Equipment for cleaning tubes in tube settler*

The Contractor shall provide complete cleaning system for cleaning the tubes in place without removing the tubes. Conceptual arrangement is cleaning by jetting.

The length of the hose provided shall be adequate to reach all the tube settlers.

7.15 Dissolved Air Floatation (DAF)

DAF shall be provided to treat clarified water to eliminate the rest over floating material. Sufficient provision shall be given to isolate and bypass the DAF in case not required. In case of bypassing the facility shall be provided to clean the DAF system completely so that seawater is fully drained and replaced by the potable water to avoid the corrosion of the civil and mechanical system during idle condition.

7.16 Dual Media Filtration

Dual Media Filtration (DMF) shall be provided with all mechanical gates and valves. Minimum 8-10 valves/gates will be there in each filter. Each filter will have two beds. The mechanical items shall be provided as per the process details provided in Part-2 A3 of bid document.

7.17 RO System

RO system shall be constructed mostly of SS316/SS316L/Duplex steel in the low-pressure area and of Super Duplex Steel in the high-pressure area and PVC/FRP/HDPE for other associated items. The selection of materials for RO system shall be proposed after discussion with the Employer’s representative. All material selection shall be approved by the Employer’s representative before procurement of equipment.

7.18 Thickeners

The circular reinforced concrete thickeners tapering at bottom shall be provided for sludge thickening. The suspension from sludge balancing tank shall be fed to thickeners. Design shall be such that the sludge can become compacted and can be extracted from the bottom. Interstitial liquid flows through peripheral weir at top. Tanks shall be deep enough to allow the sludge to settle. At least 50 cm freeboard shall be provided. Provision shall be made to remove the sludge from top if there is a serious risk. Provision shall be made for collection of thickened sludge and pumping it to BFP.

A full diameter bridge with central drive shall be provided with central platform for the installation of the scrapers and their drives and for the local control panel; a radial scraper system with bottom scraper blades, suspended on the bridge.

The thickeners shall have a full diameter fixed bridge complete with 1200mm walkway for personnel access to the centre, access stairs to ground level and hand railing, a motor driven sludge scraper complete with all necessary controls, delivery pipe work, a stilling well and overflow steel weir plates. Walkways, access steps etc shall be galvanised. Handrails shall be of tubular Type 316 steel construction and made of 32NB pipes. Especially where mild steel is proposed for underwater structure, the part shall be coated with polyurethane.

The scraping gear shall be supported from the tank base and from a fixed bridge carrying the central electrical drive for the rotating gear. The equipment including driving motor, gears, shafting and scrapers shall be designed for continuous operation and sized for the most arduous operating condition including starting from rest with an accumulation of sludge in the thickeners. The electric motor, gearbox etc., shall be provided with a sunshade.

The fixed bridge, access steps and the feed well shall be galvanised steel. The main drive shall be cast Iron construction and shall be enclosed in a dustproof enclosure with oil bath lubrication. All underwater hardware shall be of Type 316L stainless steel/ cupronickel. All fasteners shall be Monel 410/K500. All other material shall be corrosion resistant.

Suitable overload protection for the drive shall be provided to ensure that the sludge shall not overload the equipment and emergency stop pushbutton shall be provided. The scrapers shall be fitted with rotation monitors and over torque protection to alarm in the event of a failure.

Corrosion allowance of 2 mm shall be taken in the structural sections of scraper arm, bridge etc. Structural design calculations shall be submitted for all structures including scraper arm, bridge etc. and also the calculation for drive head selection including the Torque Rating.
V-notch weir in SS 316L construction of size minimum 4 mm thick and 250 mm wide shall be provided along the launders for uniform draw-off of the overflow. The weir plate shall be fixed to the launder by means SS 316L grade clamping plates and fasteners. The weir plate shall be adjustable to achieve uniform level.

The hydraulic equipment will consist of the SS 316 inlet pipe (runs along the bridge) to the central feed well of the thickener; sludge draw-off pipe with an manual & Motorised Knife Gate valve (in Duplex SS material of construction) for intermittent operation according to an adjustable timer; a drain pipe with manually operated gate valve for the complete emptying of the unit; a discharge pipe from the peripheral collecting channel to the upstream of fine screens either by gravity flow or with pump.

The sludge thickener mechanism shall be generally in SS316/GRP/Polyurethane construction, suitable for installation in a circular RCC tank and shall include the following:

a) Mechanism support beam spanning the diameter of the tank
b) Walkway (GRP) and handrail SS316 from the edge to the centre of the tank
c) Drive mechanism with internal gear type
d) Reduction gear box
e) Chain and sprocket with guard
f) Central shaft with scrapper arm and picket fence
g) Skimmer Scum Baffle and Scum trough
h) Overflow weir:
i) Vertical pickets
j) Torque Indicating Device
k) Overload Alarm protection

7.19 Chlorine Solution Delivery Pipe Work and Valves

The Contractor shall provide all necessary rigid pipe work, valves and fittings for the delivery of the chlorine solution from pumps to the points of application.

The chlorine solution delivery lines shall be of high CS ebonite lined or approved equivalent. The pipe work shall be adequately protected externally against corrosion and installed complete with necessary supports, thrust restraints, etc., and incorporate sufficient flexibility to allow for any thermal expansion effects.

When selecting material for pipe work, consideration shall be given to the deteriorating effect on some synthetic materials due to the action of ultra-violet rays. Where such materials are employed, particularly in the case of uPVC, pipe work shall be shielded from direct sunlight.

The valves in the chlorine solution pipe work shall be of forged steel body, monel spindles, stainless steel seats and PTFE gland packing or carbon steel, monel plug, PTFE sleeved plug, flanged, or approved equivalent. Locking devices and position indicators shall be provided. The diaphragm of the valves shall be PTFE faced with a backing of viton synthetic rubber (co-polymer of vinylidene fluoride and hexa fluoropropylene).

Test pressure for the solution delivery pipe work, valves and specials shall be twice the working pressure or 1.5 times the shut-off head of the injector motive water pumps, whichever is higher.

7.19.1 Chlorine Solution Distributors & Injection Fittings

Where chlorine solution is to be dosed into flow in an open channel, chamber or downstream of a hydraulic jump it shall be applied using a chlorine solution distributor.

The distributor shall be either tube drilled ceramic tubular diffuser, designed to ensure uniform distribution of the specified flow rate of chlorine solution at the point of application.

The materials of construction of the distribution and sealing shall be compatible with 3500 mg/l chlorine solution at operational fluid temperature up to 33°C. Porous ceramic material where used shall be inert, and non-toxic, uPVC tube where used shall conform to BS:3505 Class 'E'.

The distributor shall be adequately supported and designed to withstand the stream velocity at the point of application and any flow or turbulence induced vibrations.

Where chlorine solution is to be dosed into flow in pipe lines it shall be applied using an injection fitting/device designed for specified duty flow rate with isolation valve. If chlorine solution is dosed in water diffuser shall be provided. The diffuser shall be properly secured to restrain movement due to turbulence.

The injection tube shall extend across the pipe bore and be supported with ends located in diametrically opposite flanged branches.

The injection fitting shall be installed in diametrically opposite flanged branches with their axis making an angle of 45° with the horizontal in a plane normal to the direction of flow within the pipe line.

The injection fittings shall be adequately supported and designed to withstand the flow or turbulence induced vibrations. Provisions shall include necessary support brackets also.

Chlorine solution distributors or injection fittings shall be supplied complete with necessary non-return and isolation valves.

7.19.2 **Chlorine Area Ventilation**

The Container Store area shall be made reasonably gas tight and provided with separate forced ventilation facilities. A ducted system shall be provided with a number of fan units such that even though any one unit fails reasonable ventilation would still be affected.

Inlets to the exhaust duct system shall be placed at the floor level. The exhaust system shall directly discharge air to atmosphere outside the building.

Each exhaust system shall include two sets of fans, one for continuous running giving 4 air changes per hour and the other designed for intermittent running giving 20 air changes per hour.

Movable louvers shall be provided on the inlet and outlet ports of the forced air circulation system. The louvers shall open automatically when the ventilation is started and close by gravity when stopped. Contactor starters for operating ventilation equipment shall be provided in the motor control center in the Office and Control Room as well as local to the units, and be subject to shut-down control from leak detection units.

All necessary ducting, self-closing louvered outlets, exhaust fans with external mounted control gear indicator lights shall be provided under the Contract. Special attention shall be given to materials of construction and particularly to motor protection.

7.19.3 **Safety Equipment**

Materials and equipment necessary to ensure the safety of personnel working in the vicinity and others shall be provided at each chlorine storage area.
Each set of safety equipment shall be mounted in a glass-fronted, non-locking PVC coated steel cabinet in approved locations on the outside of the Chlorine building.

Emergency showers shall be provided and shall be installed near the Chlorine storage tank. The shower shall be operated automatically by a quick acting hand or foot valve. Foot operating arrangement

Two eyebaths shall be supplied. One eyebath shall be adjacent to the shower. The eye bath unit shall be fitted with fine mesh filters with built-in pressure regulating device to ensure a safe rate of flow to prevent foreign matter being further embedded into the eye and instead flush away contamination

Water for the shower, etc, shall be drawn from the service water supply.

Following safety aids shall be provided for safe handling of Chlorine system:

a) Electrically and manually operated portable Siren for plant area and announcement system for different locations inside the plant.

b) Assembly points for staff inside the plant in case chlorine major spill.

c) Display of hazardous chemicals data sheet on plant entry gates and at the use / application in local language and in English

d) Emergency Tool box and spares

e) First Aid box

f) Wind sock

g) Portabe Emergency lights

h) Display boards of telephone/ mobile of important plant personnel, Engineers authorized Doctor, mobile van at each activity locations

All the applications, permission /license and other clearances for storage and operation of tonners and chlorination system from concerned govt. authority shall be under the scope of contractor.

Each area where chlorine is stored or used as gas or liquid shall be provided with a forced ventilation system. Air intakes shall be sized to allow uniform ventilation and positioned to prevent possible recirculation. Extract air shall be ducted from low level and discharged at high level.

The ventilation systems shall be designed to provide for general day to day use an air change rate of four per hour. Extract fans shall be heavy duty industrial pattern manufactured from chlorine resistant materials.

Ductwork shall be manufactured from U-PVC extruded sheets or circular sections complying with BS 3757 and BS 3506. Fan controls shall be linked to the gas leak detection system. Hardwired fan controls shall be provided and shall be manually controlled. An override shall be provided to operate the fans as required in the event of a chlorine leak alarm. Fan controls shall be grouped in an enclosure outside the ventilated area and shall include the following:

- fan off/on
- fan running/failed indication lights
- low and high gas leakage indication alarm light

An override facility shall be provided to permit, under manual supervision only, the ventilation fans to be operated in order to disperse gas after isolation of a gas leak. Indicator lights shall be provided at the entrances to the chlorination room and the tonner room to indicate whether the ventilation system running.

7.19.4 Chlorine Residual Monitors

One chlorine residual monitor shall be provided for monitoring the final water downstream of the each of the chlorine injection points.

The monitor installation shall be located in a covered location easily accessible for viewing and maintenance and shall be provided complete with sample pumps as necessary to ensure the continuity of the sample.

The sampling pipework complete with isolation valves, etc. shall be designed to ensure the sample reaches the monitor in a time not greater than 1 minute. The monitor drainage pipework shall permit the visual checking of the presence of flow and shall discharge to the plant drain. Sample water not passed through the monitor shall be returned to the process. The residual signals shall be displayed at the local control panel and at the central HMI. High and low chlorine residual levels shall raise alarms at the local control panel and at the central HMI.

7.19.5 Chlorination Power and Control

A combined MCC and control panel shall be provided at each chlorination plant and located in a suitable location protected from the weather and the effects of the process. The control panel shall provide facilities for the:

- display status and values associated with the chlorination systems
- duty pump selection
- annunciate alarms associated with the chlorination systems
- operator adjustment of process set points

The chlorination systems shall operate using a fixed manually/automated set dose rate. The quantity of chlorine dosed shall therefore be adjusted in direct proportion to the process flow at the dosing point through PLC/SCADA. The chlorine residual monitor to be provided shall be used for monitoring and alarm purposes.

The duty booster pumps shall be manually started at the control panel. The action of starting the duty booster pump shall start the chlorination process concerned. The operation of the room ventilation and fume detection systems shall be independent of any PLC controls and shall operate in any mode. Cable support systems throughout the chlorine installation shall be constructed of u-PVC or GRP.

7.20 Belt Filter Presses

Continuous-feed dewatering belt filter press (BFP) that uses the principles of chemical conditioning, gravity draining and mechanically applied pressure shall be used for the sludge dewatering operations. Sludge shall be first conditioned using polymer prior to dewatering on the belt filter press. The optimum polymer dosage shall range up to 5 kg/1000 kg of dry solids. Polymer (non-food grade) shall be dosed to the sludge flow via an in-line static mixer. The conditioned sludge shall be first introduced on a gravity drainage section where it is allowed to thicken. Following gravity drainage, pressure is applied on the opposing porous belts where sludge is squeezed and dewatered.

Each belt press shall be designed and sufficiently automated to involve minimal operator attention. The operation of each BFP shall be controlled by the operator at a unit control panel. Operation of each BFP and its associated dedicated sludge feed pumps, polymer dosing system, and belt washing system and other plant shall be automatic once the start-up procedure has been initiated by the operator. A low-level sensor in the thickened holding tank shall automatically stop the flow of sludge to the BFP.

The BFP shall produce a dewatered sludge cake of no less than 25% dried solids. At least 98% of the solids shall be in the dewatered cake and less than 2% of the solids shall be in the wash water. The wash water will be drained to the plant drain while the solid sludge from BFP will be transported out of the plant for appropriate disposal i.e. landfill.

The BFP shall comprise the following components. All component of the BFP will be made of SS316 or better as per application.

7.20.1 **Main Structural Frame**

The structural frame shall be of all welded construction and shall be fabricated from channel designed to adequately support all components. The design permits roll removal without requirement of disassembly of frame.

7.20.2 **Extended Gravity Drainage Section**

To maximize gravity water removal, adequate gravity drainage area shall be provided or vacuum system shall be provided to enhance drainage. A set of gravity dispersion device shall be provided to disperse sludge for effective removal of water. Dispersion devices shall be constructed of ultra-high molecular weight polyethylene. Each set of devices shall have the capability of being rotated out of the flow by handles, for maintenance purposes or process flexibility.

Sludge shall be contained within the drainage section by a barrier equipped with replaceable rubber seals on each side. The gravity drainage belt shall be supported by polyethylene grids over the complete length and width of the gravity drainage section that are also used for effective removal of gravity and capillary water.

7.20.3 **Adjustable Wedge**

Following gravity dewatering, adjustable wedge section for process flexibility shall be incorporated into the press. Gradual increased pressure shall be applied as belt passes through the adjustable wedge section.

7.20.4 **Pressure Section**

A minimum diameter roll shall be used as the initial roll in contact with gravity concentrated sludge. A S-shaped roll configuration shall be used to apply maximum pressure and shear. To ensure optimum cake dryness, a minimum number of rolls shall be used in the pressure area.

7.20.5 **Filtration Belts**

Each belt shall be a continuous design woven from monofilament polyester strands. Each belt shall incorporate a mechanical seam that does not interfere with press operation and also allows simple, periodic belt replacement.

7.20.6 **Doctor Blade**

For removal of dewatered cake, the press shall incorporate a doctor blade for each filtration belt.

Blade pressure shall be field adjustable against the belt by means of spring tensioning mechanism and shall be replaceable, reversible with two useable edges and fully accessible to the operator.

7.20.7 **Rolls**

All rolls, including guide and tracking, shall be of low deflection design.

7.20.8 **Roller Bearings**

All bearings shall be pillow block type with split, cast iron, two bolt housings. All bearings shall be capable of compensating for misalignment without seal distortion. Each bearing shall be grease lubricated.

7.20.9 **Filtrate Collection**

Drainage pans shall be located under all gravity and pressure section of the press. Drain pans with standard NPT connections shall collect gravity filtrate and pressure filtrate to common drainage points.

7.20.10 **Belt Washing Device**

Following cake discharge, each polyester belt shall be continuously washed using a high pressure, low volume steel shower assembly. A Y-strainer (stainless steel) to be provided in wash water line to remove any particles which may enter the shower assembly. Each shower assembly shall have stainless steel nozzles. The shower assembly shall be designed to completely contain the high velocity water spray and remove any solids trapped in the belt.

Pumps required for belt washing shall be integral to the BFP system. The belt washing shall be automatic with minimum flow of water. Spent washwater shall be directed to the plant drain.

7.20.11 **Belt Tracking**

Belt positioning for each belt shall be continuously and automatically monitored by an arrangement which shall be installed with guide devices. The guide device shall ride the edge of the polyester cloth belt. The micro-torque unit shall sense belt misalignment and shall automatically walk the belt back to the normal operating position by means of a live hydraulic tonner which shall be attached to tracking rolls. The opposite end of the tracking roll shall incorporate self-aligning pillow block bearings which allows the tracking rolls to pivot in a horizontal plane. Belt tracking shall be automatically operated by the hydraulic power pack. A limit switch shall be provided on each side of each belt to sense extreme belt travel and initiate a shut-down signal and sound an alarm. The limit switches for the pressure section shall be positioned to sense both belts simultaneously.

7.20.12 **Belt Tensioning**

Each belt in the pressure section shall be equipped with a hydraulic tonner belt tension system operated by the hydraulic power pack to automatically ensure proper preset belt tension while dewatering varying thickness of sludge. The belt tension system shall assure parallel movement of the tension rolls by use of rack and pinion system.

7.20.13 Belt Press Drive & Component Operation

The belt press drive shall comprise of an electric geared motor unit coupled to the drive roll through a flexible coupling. A local electrical control panel complete with control logic, variable frequency drive etc. shall also be supplied along with the belt filter press.

7.20.14 Sludge Treatment and Disposal Power and Control

A combined MCC and control panel shall be provided. The control panel shall provide facilities for the:

- display status and values associated with the sludge treatment systems
- duty pump selection
- annunciate alarms associated with the sludge treatment systems
- all necessary controls for BFP installation
- The BFP manufacturers proprietary control panel/s may be provided in addition to the above providing the requirements for BFP status and alarm annunciation are fulfilled locally and at the central HMI

7.20.15 Conveyor System

a) For the disposal of dewatered sludge, a common motor driven endless belt conveyor shall be provided. The conveyor shall be designed in accordance with IS 11592 or equivalent. The conveyor and chutes shall be suitable for handling occasional heavy objects which will cause shock loads.

b) The construction of the frame and support shall be robust and torque resistant. Belt conveyor shall be of 20 deg. trough type complete with drive assembly structures, idlers, pulleys and belt cleaners. Idlers and pulley shall be provided with anti-friction bearings.

c) The belt material shall be two ply nylon or equivalent with minimum 3 mm neoprene covering on carrying side. Splicing shall be employed to make the belt endless. The belt shall operate over three roll twenty degree, troughing idlers. The idlers shall rotate on precision type, deep groove, single row ball bearing with built-in close-fitting triple labyrinth grease seal. The ends of the outer shell shall be counter bored and a full length centre tube journalled concentricity. The outer shell, centre tube and precision die formed steel ends shall be brazed into an integral unit to provide concentricity. The ends of the centre tube shall be bored concentrically with each other after roll assembly to provide correct bearing alignment and to provide prestressing of boring. The centre tube shall be grease fit after assembly. Troughing idlers shall have means of adjustment or ensuring belt tracking. On the return run the belt shall operate over flat roll idlers having bearing, shaft and lubrication arrangements as above for carrying idlers. Spacing of idlers shall be of 1200 mm on carrying run and 2400 mm on return run.

d) The head and tail pulleys shall be manufactured from welded steel/any alloy steel and shall be provided with rubber lagging. Lagging for drive pulleys shall have herringbone grooving. Pulleys shall be equipped with taper lock bushings. The tail pulley shall incorporate a screw rake for adjusting belt tension. Head and tail pulleys shall be adequately guarded.

e) Shafting for pulleys shall be of SS316. They shall be forged, ground and polished to obtain close diameter tolerances. The head shaft shall be provided with roller bearing pillow blocks.

f) The belt conveyor shall be driven by a squirrel cage, TEFC motor. A V-belt drive arrangement shall be provided between the motor and a helical speed reducer, the latter shall be mounted on the end of the head shaft. The driving pulley shaft shall have back stops to prevent backward movement of the belt.

g) The conveyor shall be supported on appropriate channel sections with 14 gauge steel deck plate between the two runs of the belt and the necessary supports to the floor. The floor supports shall be made out of steel plates having minimum 6 mm thickness. The conveyor shall be protected from weather by a 'dog box' type canopy.

h) An adjustable belt scraper shall be provided on the hopper end of the conveyor belt. The scraper and attachments shall be of fibreglass/fibre reinforced plastic/PVC.

i) Sludge cake discharge Hoppers shall be provided to transfer the sludge cake from the BFP to the troughed belt conveyor and from the conveyor discharge to skip. The latter chute shall extend beneath the belt scraper and shall allow access for maintenance of the belt scraper. Chutes shall be designed to minimize the accumulation of rags and stringy materials.

The conveyor shall be fitted with an emergency stop operated by wire rope at foot level. Two Nos belt sway switches shall be provided on conveyor.

7.21 Hoist and Crane

7.21.1 Electrically Operated Hoists

Electric hoists shall be complete with hoisting motor, wire rope drum, wire rope, hook, necessary gearing, sheaves, electromagnetic brake for hoisting motion, weather & dust-proof push button station, contractor panel, all wiring, limit switches, etc.

Electric hoists shall conform to IS:3938 and shall be suitable for outdoor application. All the parts of the hoist shall be designed to withstand surrounding atmospheric conditions without any deterioration.

Rope drums shall be either cast or welded to sustain concentrated loads resulting from rope pull. Drums shall be machine grooved right and left with grooves of a proper shape for the rope used.

Gears shall be cut from solid cast or forged steel blanks o r shall be of stress-relieved welded steel construction or built-up from steel billets and welded together to form a one-piece gear section.

Hoist ropes shall be extra flexible, improved plough steel rope with a well lubricated hemp core and having six strands of 37 a wires per strand with minimum ultimate tensile strength of 1.6 x 106 kN / sq. m.

Hooks shall be solid, forged, heat treated alloy or carbon steel of rugged construction of the single hook type and provided with a standard depress type safety latch.

Hoisting motor shall be equipped with electrically released, spring set, friction shoe type brakes having torque capable of holding 125% of the full rated hook load. Brake shall apply when either the motor controller or the main power switch is in 'OFF' position or in the event of power failure.

Drive motors shall be designed for frequent reversal, braking and acceleration and shall be as per IS:325. Pendant control switch, controllers and resistors, controls, electrical protective devices, cables and conductors, earthing guards etc. shall be as per IS:3938. Limit switches shall be provided for over-hoisting and over-lowering.

The electric hoists shall be of Class II duty.

A 25% overload test, speed tests, limit switch tests and brake test shall be conducted for the hoist and trolley at manufacturer's works.

7.21.2 Hand Operated Hoists and Trolleys

Manual hoists shall be complete with hand-chain, trolley, pulley block, hook, hand and load chains, brake and other accessories. They shall comply with the latest applicable standards, regulations and safety codes in the locality where equipment will be installed.

Each hoist shall be operated on a monorail (I-Beam). The factor of safety shall not be less than 5. The load chain may be heat-treated to give ductility, toughness and conforming to IS:3109/BS:1663/BS:3114. The load wheel is to be made from heavy duty malleable castings. The hand chain is to conform with BS:6405:1984 and hand chain wheel may be made from pressed sheet steel with roller type guarding. Gears shall be cut from solid cast or forged steel blanks or shall be stress – relieved welded steel construction. Pinions shall be of forged carbon or heat-treated alloy steel. Strength, Quality of Steel, heat treatment, face, pitch of teeth and design shall confirm to BS:436, BS:545 and BS:721. Spur and helical gears must comply with BS:436 and worm with BS:721. Bearing must be ball and roller type conforming to IS:2513/BS:2525-32:1954. Proper lubricating arrangements are to be provided for bearings and pinions. The brake for the lifting gear shall be automatic and always in action.

The proof testing of each chain pulley block is to be carried out as per latest applicable standards. The safe working load is to be marked in such way that is clearly visible from the operating level.

7.21.3 Hand Operated Travelling Crane

The crane bridge shall consist of a single bridge girder carrying two wheels at each end of the span. Steel used shall be tested quality steel conforming to IS 2062. The girder shall have enough strength to carry the test load without causing undue stress or deflection.

The long travel bridge wheels shall be rim toughened, heat treated carbon steel or low alloy steel or C.I. They shall be double flanged type. The wheels shall have antifriction ball/roller bearings. The wheels shall be machined on their treads to match the runway rail section. The bridge shall have a geared shaft and pulley connecting to opposite wheels of the span, to achieve the long travel motion of the bridge, by means of a chain. The runway rails of adequate strength and rigidity, rail clamps and other accessories for mounting the rails and suitable end stops for the bridge shall be supplied by the Contractor.

The chain pulley block shall be operated on the lower flange of the bridge girder.

The load chain shall be made of alloy steel as per IS:3109. It shall be heat treated to give ductility and toughness so that it will stretch before breaking. It shall be of welded construction with a factor of safety not less than 5.

The hand chains for the hoisting and traverse mechanism shall hang well clear of the hook and both the chains shall be on the same side. The hand chain wheel shall be made from pressed sheet steel and shall be provided with roller type guarding to prevent snagging and fouling of the chain.

All the gearing shall be totally encased. Proper lubricating arrangements shall be provided for bearings and pinions. Gears shall be cut from forged steel blanks. Pinions shall be of heat treated alloy steel. Gears shall be as per BS:436/IS:4460.

The trolley track wheels shall be rim toughened, heat treated carbon steel or low alloy steel or C.I. and shall be single flanged and shall have antifriction ball bearings. The wheels shall be machined on their treads to match the flanges of the track joints.

The travelling trolley frame shall be made of rolled steel conforming to IS:2062. The side plates of trolley frame shall extend beyond wheel flanges, thus providing bumper protection for the wheels. The two side plates shall be connected by means of an equalising pin.

Axles and shafts shall be made of carbon steel and shall be accurately machined and properly supported.

The lifting hooks shall be forged, heat treated alloy or carbon steel of rugged construction. They shall be of single hook type provided with a standard depress type safety latch. They shall swivel and operate on antifriction bearings with hardened races. Locks to prevent hooks from swivelling shall be provided. Hook shall be as per IS:3815.

The brake for the lifting gear shall be automatic and always in action. It shall be of screw and friction disc type self-actuating load pressure brake. Brakes shall offer no resistance during hoisting.

Ratchet and Pawl mechanism shall be provided to arrest the full load from lowering due to gravity. The ratchet and pawl shall be of steel, hardened and tempered so as to attain required wear resistance and toughness.

7.21.4 **Electrically Operated Overhead Travelling Crane**

The crane shall be electrically operated, bridge type complete with all accessories including down shop conductor, crane rails and fixtures, and shall conform IS:3177 or relevant internationally approved standards.

The crane bridge shall consist of bridge girders on which a wheeled trolley is to run. The bridge trucks and trolley frames shall be fabricated from structural steel. Access walkway with safe hand railing as is required along the full span length of the bridge girder. Steel shall be tested quality conforming to ASTM A36 except that, plates more than 20 mm thick shall conform to IS:2062, or relevant internationally approved standards. The bridge shall be designed to carry safely the loads specified in IS:807 or relevant internationally approved standards. All anti-friction bearings for bridge and trolley track wheels, gear boxes and bottom sheaves on hook shall be lubricated manually by hand operated grease pump through respective grease nipples.

Wheel base and structural frame of the wheel mounting of the end carriages shall be designed so as to ensure that the crane remains square and prevent skewness. Bridge and trolley track wheels shall be of forged steel and shall be double flanged type. The wheel diameter and rail sizes shall be suitable for the wheel loads. The crane rails shall be manufactured from wear resistant austenitic manganese steel. Mountings of the wheels shall be designed to facilitate easy removal for maintenance. Walkways shall be at least 500 mm clear inside width with a 6 mm thick non-skid steel plate surface. Steel rail stops to prevent rails from creeping and trolley from running off the bridge shall be abutted against ends of rails and welded to the girders. Bridge and trolley stops to match the wheel radius shall be provided before the buffer stops.

All exposed couplings, shafts, gear, wheels, pinions and chain drives etc. shall be safely encased and guarded completely to prevent any hazard to persons working around. All bearings and gears shall have a design life of 100000 hours. Electro-magnetic and hydraulic thrustor brake shall be provided for the main hoist. One electro-magnetic brake shall be provided for each of the cross travel and long travel motions.

Hook shall be solid forged, heat treated alloy or carbon steel suitable for the duty service. They shall have swivels and operate on ball thrust bearings with hardened races. The lifting hooks shall comply with the requirements of IS 8610 or relevant internationally approved standards and shall have a safety latch to prevent rope coming off the hook.

Hoist rope shall be extra flexible, improved plough galvanized steel rope with well lubricated hemp core and having six strands of 37 wires per stand with minimum ultimate tensile strength of 1.6×10^6 kN/m2 of Right Hand Ordinary (RHO) lay construction. The ropes shall have a 6:1 safety factor on the specified safe working load, and shall conform to IS:2266. Rope drums shall be grooved and shall be either cast iron or cast steel of or welded steel conforming to IS:3177, BS:466 or relevant internationally approved standards.

Gears shall be cut from solid cast or forged steel blanks or shall be stress relieved welded steel construction. Pinions shall be of forged carbon or heat-treated alloy steel. Strength, quality of steel, heat treatment, face, pitch of teeth and design shall conform to applicable standards.

Name Plate showing the capacity, year of manufacture and rated capacity of hoist, in figures not less than 150 mm height, shall be placed on each side of the crane girder.

The maximum deflection under full load shall not exceed 1/900 of the span (as per IS:3177).

All accessory and auxiliary electrical equipment including drive motors, electrically operated brakes, controllers, resistors, conductors, insulators, current collectors, pendant push button station, protective devices, operating devices, cables, conduits, etc. necessary for the safe and satisfactory operation of the crane shall be provided.

Power to the crane shall be provided by down shop conductors manufactured from high conductivity hard drawn copper. Conductors shall be completely shrouded such that they have no exposed current carrying surfaces. Pendant type push button station shall be sheet steel enclosed and shall comprise the following push buttons and indicating lamps:

a) `Start' and `Stop'.
b) Long travel - `Right' and `Left'.
c) Cross travel - `To' and `Fro'.
d) Hook - `Hoist' and `Lower'.
e) Red indicating lamp for supply `ON' indication.

Pendant type push button shall be supported independently of the electrical cable and shall be earthed separately, independent of the suspension. Automatic reset type of limit switches shall be provided to prevent overtravel for each of the following:

a) For `UP' and `Down' motions of the hook.
b) Long travel motion
c) Cross travel motion

Crane structures, motor frames and metal cases of all electrical equipment including metal conduit and cable guards shall be earthed. All motors, brakes, limit switches, panels, drum controllers, resistor unit sets shall be provided with two studs for earthing.

All motors shall be of the quick reversing type with electric mechanical brakes suitable for the duties specified. All movements shall be electrically powered suitable for operating with the hook loaded. Facilities shall be provided for the accurate location of the hook by means of `inching' the cross travel and down shop travel motions.

Sufficient slings, ropes, shackles, lifting beams, etc shall be supplied to handle all items of plant covered by the crane. They shall be labelled or marked with the Safe Working Load (SWL) and the purpose for which they are intended.

The crane, and all slings, ropes, shackles and other lifting equipment supplied shall be tested by the manufacturer at his works. The tests shall be carried out at 125% of Safe Working Load, and Test Certificates shall be supplied.

The Contractor shall include with the cranes all necessary contactors, control cubicles and protection equipment necessary to operate the crane and provide adequate electrical protection against overload, phase and earth fault and fail-safe protection in the event of an interruption in the power supplies. All access ladders and platforms necessary to carry out maintenance and repairs shall be provided and installed by the Contractor.

All electrical equipment shall be fully tropicalised.

Site tests shall be carried out by the Contractor who shall supply the necessary materials for the test load. The test load shall be removed from site by the Contractor after successful tests have been carried out.

7.21.5 Jib Cranes

Fixed jib cranes shall be provided in for lowering/removal of equipment/parts. The crane capacity shall be 1.25 times the maximum weight to be handled or 1.5 Tonnes, whichever is more. The lift and reach of the cranes shall be suitable for the equipment/parts to be handled. The crane shall be capable of being swivelled by 360. Adjacent halves of clarifiers may be provided with common jib crane if feasible. All materials used in the construction shall be corrosion resistant. Mild steel used shall be galvanised. Ropes, chains and pulleys shall be of stainless-steel construction. Hardware shall be of SS 316. The Jib crane shall also be provided for handling submersible mixers in Waste water balancing tank, thickened sludge sump (sludge holding tank) and Backwash recovery tank (Backwash Waste water tank).

7.22 Reduction Gear Units

Reduction gear units, wherever provided shall be double reduction units without V-belt and pulley. Gears shall be cut from solid cast or forged steel blanks or shall be of stress relieved welded steel construction. Pinions shall be of forged carbon or heat-treated alloy steel. Strength, quality of steel, heat treatment, face, pitch of teeth and design shall conform to applicable standards. Split gears shall not be used. Gears and pinions shall be pressed on and keyed to shafts. All pinions and gears are to be of the totally enclosed type up to the last stage of reduction in all motions and shall be carried in fabricated steel gear cases which must be dust-proof and firmly sealed to prevent oil leakages and shall be oil bath lubricated. The gear boxes shall have covers split horizontally and arranged so that top half can be removed for inspection. They shall be fitted with bolted type machined inspection covers and with cast steel cartridge housings for carrying roller bearings. Dip sticks or indicator shall be provided for indicating the oil level. Guards shall be strong enough to retain the whole gear or any part that might otherwise fall. No overhanding gears shall be used. Drain plugs shall be provided on all gear cases. Lifting lugs shall be provided for handling purposing.

7.23 Ventilation System

7.23.1 Scope

The scope of work covers the design, manufacture, inspection and testing of performance at the manufacturer's and / or his sub-contractor's works delivery to site, storing and handling at site, erection, commissioning and carrying out acceptance tests at site of the Ventilation System for Desalination Plant and its buildings.

7.23.2 Code and Standard

The design, manufacture, inspection and testing of ventilation system shall comply with all currently applicable statutes, regulation and safety codes in the locality, where the equipment are to be installed. The equipment shall also conform to the latest applicable Indian / British /

American Standard. Nothing in this specification shall be construed to relieve the contractor of his responsibility. In particular, the equipment shall conform to the latest edition of the following standard.

IS: 2312	Propeller type AC ventilation fans
IS: 3588	Specification for Electrical Axial flow fans
BS: 848	Fans: Part 1: Methods of testing performance; Part 2: Fan Noise Testing
AMCA: 210	Test Code for Air Moving Devices
BS:6540(Part-1)	Method of test for air filters used in air conditioning & General Ventilation.
BS: 3928	Sodium flame test for air filters (other than for air supply to I.C. Engines & Compressors).
VS-FED-2098	Method of cold DOP & Hot DOP test MIL - STD-282 DOP smoke penetration method.
ASHRAE-5276	Method of testing air cleaning device used in general ventilation for removing particulate matter

In case of any conflict in the standard and this specification, the decision of Employer shall be final and binding.

7.23.3 **Description of Ventilation System**

The inside dry bulb temperature (DBT) temperature to be maintained shall be limited to maximum 5 ^oC over than the ambient dry bulb temperature at all times of the year considering ambient air conditions mentioned above.

The following are the areas provided with mechanical type ventilation system with combination of supply air fans and / or exhaust air fans/TURBO ventilators (Roof ventilators, wall mounted type)

a) All pump houses
b) UF Building
c) DAF and Lamella Buildings
d) RO Building
e) Chemical House
f) Lime Filters in case of Potablization
g) Toilets in the buildings including the following (30 Air Changes per Hour)

7.23.4 **Design Philosophy**

Number of air changes per hour in evaporative / mechanically ventilated areas shall be as follows.

S. No.	Area	Air Changes per hour
1.	Chemical Houses, Pump (enclose) houses &	20

	Other areas like toilets etc.	
2.	RO buildings and over	40

However, in areas producing lot of heat, the temperature limitation should be the criteria, which is as follows:

a. Inside dry bulb temperature shall be minimum 5 ^{o}C below the design ambient temperature during summer for evaporative cooled areas.

b. Inside dry bulb Temperature shall be maximum 3 ^{o}C above the design ambient temperature during summer for mechanically ventilated areas.

The criterion which gives higher number of air changes / higher quantity of air in either of the conditions as mentioned above shall be the basis for selecting the required air flow for that area.

All ventilation system shall operate on 100% fresh air. All mechanically ventilated areas shall be positively ventilated by means of supply air fans, generally in combination with exhaust fan / gravity operated back draft damper. The ventilation system shall be designed for continuous operation of 24 hours a day. All GS sheets shall be hot dip galvanized or spray galvanized unless otherwise specified and minimum zinc deposition shall conform to class 275 of IS 277.

7.23.5 **Equipment Description**

7.23.5.1 *Axial Flow Fans*

These fans shall have single piece cast aluminum impeller with blades of aerofoil design.

The fan casing shall be of heavy gauge sheet steel construction minimum thickness of 3 mm up to a fan diameter of 750 mm, 5 mm for fans with impeller diameter of 750 mm and above and the same shall be spray or hot dip galvanized.

Necessary rain protection cowl, inlet and outlet cones, bird protection screen, adjustable damper, vibration isolators, back draft dampers etc. shall be provided.

The speed of the fan shall not exceed 960 rpm for fan with impeller diameter above 450 mm and 1400 rpm for fan with impeller diameter 450 mm or less. However, for fans having static pressure of 30 mm WC or above the speed of the fan shall not exceed 1440 rpm for fan with impeller diameter of above 450 mm and 2800 rpm for fan with impeller diameter of 450 mm or less. The first critical speed of rotating assembly shall be at least 25% above the operating speed.

All other accessories like supporting structure etc. as required shall be provided.

7.23.5.2 *Air Filters*

a) Pre - filter

Filter medium shall be either fabric or metallic type consisting of

i) Fibrous material (extruded polyethylene) or felt filter fabric Dry type with element of 5 ply construction for Fabric type.

ii) V-fold galvanized wire mesh inters spaced with a flat layer of galvanized wire mesh for Metallic type pre-filters.

b) Frame

Gl sheet (minimum 18 gauge thick) or Aluminum alloy of (minimum 16 gauge) supported by galvanized steel wire mesh of 10 mm square with handles.

c) Other requirements

Suitable aluminum spacers be provided for uniform air flow; Casing shall be provided with neoprene sponge rubber sealing. Filter shall be capable of being cleaned by water flushing. Wire mesh edges shall be suitable hemmed to eliminate the danger of abrasion during handling

d) Efficiency:

Average arrestance of 65 - 80% when tested in accordance with BS: 6540/ASHRAE -52 - 76.

e) Minimum thickness shall be 50 mm.

f) Face velocity shall not be more than 2.5 m/sec.

g) Pressure drop (Initial pressure drop) shall not exceed 5.0 mm WC at rated flow. Final Pressure drop - Up to 7.5 mm WC.

7.23.5.3 *Fine Filter (Micro-vee type)*

a) Construction -

By pleating a continuous sheet of filter medium into closely spaced plates separated by heavy corrugated aluminum spacers

b) Frame:

Aluminum alloy of (Minimum 16 gauge conforming to IS: 737) with handles.

c) Other requirements

A neoprene sponge rubber sealing shall be provided on either face of the filter frame. Shall be capable of being cleaned by air or water flushing.

d) Efficiency:

Average arrestance of 80-90% when tested in accordance with BS: 6540/ASHRAE -52 - 76.

e) Thickness:

150 or 300 mm

f) Face Velocity:

Not more than 1.2 m/sec for 150 mm and not more than 2.4 m/sec. for 300 mm size.

g) Pressure drop:

Initial pressure drop - not to exceed 10 mm WC at rated flow. Final pressure drop - up to 25 mm WC.

7.24 Fire Extinguishers

Portable fire extinguishers are to be provided for all units as per the requirement of Tariff Advisory Committee (TAC) or meeting the requirement of local regulations whichever is stringent. All the extinguishers shall have ISI mark / TAC approval.

7.1.1 Firefighting Water Pumping Subsystem

This subsystem is, basically, composed of the dedicated pump house and of the pumps and other equipment, such as Diesel fuel oil tank, etc.

The following are the major equipment items:

- electric driven fire fighting pump
- diesel driven fire fighting pump
- Minimum Two (2) Jockey pumps (One (1) for duty, One (1) for stand-by)
- Accessories: pipework, pump controller, etc.

7.1.2 Indoor and Outdoor Hydrants Subsystem

7.24.1.1 *Indoor Hydrant subsystem*

The indoor hydrants and the related hose reel cabinets will be provided inside the following buildings:

- Intake Pump house building
- Lamella and DAF Building
- Filter House
- R.O Building
- Chemical Dosing Building
- Electrical & Control room Building
- Gas Chlorination Building
- Workshop & store Building
- Air Compressor Building
- Fire Fighting Pump House
- Any Other building that is deemed necessary

The indoor hydrant system shall be served by the hydrant main isolated pipe.

7.24.1.2 *Outdoor Hydrant Subsystem*

The outdoor hydrants subsystem is provide to protect the desalination units and remineralization plant areas etc. The outdoor hydrants and the related (fire) hydrant cabinets shall be located at strategic locations along the hydrant main. The spacing between the hydrants shall not exceed 80m.

7.24.2 **Portable fire Fighting Subsystem**

The fire Extinguishers distributed all over the water plant building shall be suitable to be operated by the operating personnel of the respective buildings. This will allow a quick response to fires at early stage. Various types of portable extinguisher shall be provided.

The following portable extinguishers shall be provided:

- Carbon Dioxide Extinguisher
- Dry Powder Extinguisher

The fire extinguishers will be reasonably provided inside the buildings according to NFPAcodeiO.

All the extinguishers shall have ISI mark approved.

7.24.3 **Fire Detection, Monitoring and Alarm System.**

A manual and automatic fire detection and alarm system shall be provided with detection devices, selected to suit particular risks and with a control system designed to provide operation and fire brigade staff with sufficient information to identify and respond correctly to any fire detected.

To ensure that the fire is detected at an earlier stage, the areas of high risk shall be monitored with automatic fire detectors. The following types of detectors are used:

- Smoke detectors (Optical),
- Flame detectors,
- Heat detectors.

In addition to the automatic fire detectors, non-automatic fire alarms (manual push button alarms) shall be installed at the entrances to the acoustic enclosure and at the building exists.

Each fire detector and manual push button alarm fo the fire alarm system shall be labelled in such a way that it is possible to identify to which group the fire detector or manual push button alarm belongs.

A signal will initiate an alarm (in the central control room) and indicates the related fire detector. The detection / initiation signal of water plant from automatic / manual fire initiation devices will be summarized at local control panel, and zone fire alarm signal will be transferred to the main fire alarm panel at central control room.

The annunciator panel will be installed in the Central Control room.

In addition to the automatic fire detector, non-automatic fire alarms (manual push button alarms) are installed at the entrances to the acoustic enclosure and at the building exits.

7.25 Propeller Exhaust Fan

The fan should comply with IS:2312. The blades shall be of mild steel and properly balanced so as to avoid noise and vibration. The blade and blade carriers shall be securely fixed so that they do not loosen in operation. The means provided for securing the fan mounting or fan casing to the wall partition or window shall be such as to provide a secure fixing without damage to the fan or wall.

Suitably designed guards shall be fitted to the inlet and the outlet side to prevent accidental contact. No flammable material shall be used in the construction of fan. Moulded parts, if used, shall be of such materials as to withstand the maximum temperature attained in the adjacent component parts.

The fan shall have protective insulation or be capable of being earthed. A fan with protective insulation may be of all insulated construction or have either double insulation or reinforced insulation. Each fan should be provided with a 10 sq.mm mesh bird screen. The sheet used for the cowl should be 14 G and Motors shall be TEFC, IP-54.

Fans used to extract from areas storing or handling chlorine/ chemicals shall be constructed from materials resistant to attack by chlorine/stored chemical.

7.26 Air-conditioning Equipment

The air conditioning units shall be of split type, with the outdoor condensing unit mounted on the terrace of the room or grouted on external side of the wall with suitable brackets. Unless otherwise specified, equipment shall conform to the latest applicable Indian or IEC Standard. Equipment Complying with other authoritative standards such as British, USA, ASHRAE etc. will also be considered if it ensures performance equivalent of superior to Indian Standard.

7.26.1 Proposed Areas to be Air Conditioned

- All Control rooms
- Complete Administrative building
- Laboratory rooms
- All MCC Rooms,
- Battery rooms in various buildings.

7.26.2 Type of Air Conditioning Units

7.26.2.1 *Design Capacity up to 3TR*

Split type AC unit: Non-ductable unit with outdoor type air Cooled condensing unit (2 x 100% capacity for each areas and fan-coil (evaporator) units (2x100%) distributed / placed at desired locations in the area which is air-conditioned. Condensing unit may be located in the roof of the building with local sunshade cover and approach through stair case up to the roof.

7.26.2.2 *Design Capacity above 3 TR and up to 10 TR*

Packaged Air Conditioner: Ductable with outdoor type Air (2 x 100% capacity) Cooled condensing (outdoor) units and indoor evaporator (2 x 100%) units placed inside the plenum area (in the space between ceiling and false - ceiling); Air supply distribution shall be through duct and return air shall be through plenum space to evaporator unit. Condensing unit may be located in the roof of the building with local sunshade cover and approach through stair case up to the roof.

7.26.2.3 *Design Capacity above 10 TR up to 50 TR*

Indoor type, ductable air cooled, Packaged Air (2 x 100% capacity) conditioners shall be provided for each area / building. The PAC room shall be located in proximity to the area to be air-conditioned.

The capacity of PAC and other equipment shall be designed as per the Design Philosophy & Equipment specification elaborated below. Sizing calculations for all the equipment shall be submitted for approval of Employer.

The Split (SAC) type AC & PAC units shall be air cooled type.

Number of fresh air changes per hour shall be minimum 1.5 or minimum 0.45 cum/min per person (16 cfm) whichever is higher for Conference rooms / common rooms.

The occupancy for general / office area shall be minimum one person per 10 sq. and for conference room the same shall be one per 3 sq. m for design of AC System. In the control rooms, control, equipment rooms etc., the occupancy may be one person per 25 sq. m (Minimum).

All the equipment of Air Conditioning system shall be designed for continuous duty. In Air conditioning system provided with ducts, false ceiling shall be provided with appropriate under deck insulation.

A minimum design margin of 15% shall be considered while sizing AC Plant Capacity.

All GS sheets (duct material) under Air conditioning system shall be not dip galvanised or spray galvanised unless otherwise specified and minimum zinc deposition shall conform to class 275 of IS:277.

7.27 Air Hose Apparatus

It shall consist of full vision face mask with inhalation and exhalation valve, connected to a corrugated tube ending in a manifold non-return valve, mounted on a harness belt worn around the waist, tested to applicable IS. The 50m long, 20mm canvas reinforced wire embedded hose, connected to the manifold shall be uncrushable and shall not kink.

The radial blower connected to the hose shall be housed in a strong carrying box which can hold the breathing apparatus with hose and fittings. The blower shall be suitable for supplying air to two people simultaneously.

7.28 Safety

Safety signs All signs providing health and safety information on instructions shall comply with BS: 5499-5:2002 and equivalent local standards. Signs shall be of durable quality and shall comprise a substrate of 22 gauge aluminum, predrilled for fixing and with radiuses corners free of burrs or sharp edges. Symbols and lettering shall be screen printed.

7.29 Quality

Product of an experienced Equipment manufacturer should satisfy the following criteria:

a) Shall demonstrate equal or larger capacity installations using similar equipment

b) Equipment installed and successfully operating for at least five years having specified constructional features equal to or higher than the specified size and rating. This shall be supported by certificates from the end users.

c) Provide names and phone numbers of contacts at referenced installations to verify performance

d) Demonstrate to satisfaction of the Engineer that equipment to be provided is equal to that specified

7.30 Warranty

a) Comply with the requirements of each type of equipment and specification mentioned elsewhere in this document

b) Warrant all components to be free of defects in materials or workmanship for 12 months from date of satisfactory completion of performance and process proving tests

c) Individual warranties by component manufacturer in lieu of single source responsibility by the main equipment manufacturer shall not be acceptable

d) Items which fail during the warranty period and the period of operation and maintenance under the Contract, excluding expendable items, shall be replaced without cost to the Employer

e) Provide manufacturer's guarantee and warranty certificates prior to equipment start-up

7.31 Packing and Protection

Before any Plant is dispatched from a manufacturer's factory it shall be adequately protected and packed to ensure that it will arrive on the Site in an undamaged condition. The methods employed for protection and packing must be suitable for withstanding the conditions which may be experienced during shipment, delivery to the Site and prolonged periods of storage in the open, whether the items are shipped in packing cases, crates or only partially protected according to their nature.

Bright parts and bearing surfaces shall be protected from corrosion by applying a rust preventive lacquer, high melting point grease or similar temporary protection. A sufficient quantity of solvent shall be supplied with the plant to enable this coating to be removed on the Site.

All machined flanges and other mating surfaces shall be protected by means of wood templates. The bolts for securing these templates shall not be reused in the final installation.

No one crate or package shall contain items of Plant intended for incorporation in more than one part of the Works. All items of Plant shall be clearly marked for identification against the packing list, which shall be placed in a waterproof envelope inside every packing case or crate.

Every packing case and crate shall be indelibly marked to show its weight, serial number, top and bottom, shipping marks and handling instructions or sling marks. Electrical Plant shall be enclosed in sealed airtight packages with dehydrating material, before being placed in packing cases on shock-absorbent material and secured by means of battens.

8. GENERAL ELECTRICAL & INSTRUMENTATION REQUIREMENTS

8.1 Introduction

The general requirements include design, manufacture, testing at works, supply and delivery at site, unloading and storing the equipment at site, installation, testing and commissioning of all electrical equipment are covered under this section of Specification.

All the electrical and instrumentation equipment to be supplied under this contract, like 33kV / 3.3KV, 3.3 KV/0.415KV Power Transformers, 33 KV, 3.3 KV Switchgears, 3.3 KV Capacitors, 415V capacitor bank with APFCR, 415 V Switchgears, 415V PMCC & MCC, Distribution board, Battery, Battery Charger, DC Distribution Board, 33kV, 3.3 KV and LT Cables, Digital Panel Meters, Protective Relays, Instrumentation and SCADA system etc as per process requirements shall be of reputed makes. The equipment of those manufacturers, who have sufficient proven experience of manufacturing the respective equipment of similar capacity, shall be considered. The respective equipment should have been manufactured, supplied, installed, Commissioned successfully and should be running satisfactorily since last 5 years continuously. Certificates from the end users, regarding their satisfactory Performances, shall have to be submitted in this regard.

8.2 General

For uniformity of appearance all switchgear and control panels shall have a common appearance and colour.

In order to reduce the spares holding to a minimum electrical, control and instrumentation components of a similar type and purpose used throughout the Works shall, unless it can be shown by the Contractor, to be impractical be of the same manufacturer and type / series.

8.3 Abbreviations

For the purpose of these Requirements the following abbreviations of electrical terms have been used.

Symbol	Abbreviations	Symbol	Abbreviations
R	red phase	MCB	Miniature Circuit Breaker
Y	yellow phase	MCCB	Moulded Case Circuit Breaker
B	blue phase	ELCB	Earth Leakage Circuit Breaker
ac	alternating current	RCD	Residual Current Device
dc	direct current	MCC	Motor Control Centre
A	Amp	PFC	Power Factor Correction
mA	Milliamp	PF	Power Factor
V	Volt	CP	Control Panel

kW	Kilowatt	LCP	Local Control Panel
kVA	kilovolt amp	UPS	Uninterruptible Power Supply
kWh	kilowatt hour	PLC	Programmable Logic Controller
MVA	megavolt amp	I / O	Input / Output
Hz	hertz (cycles per second)	R I / O	Remote Input / Output
SP	single pole	SCADA	Supervisory Control And Data Acquisition
SPN	single pole and neutral	HMI	Human Machine Interface
DP	double pole	LAN	Local Area Network
TP	triple pole	OS	Operator Station
TP&N	triple pole and neutral	PC	Personal Computer
SP&SwN	single pole and switched neutral	SPD	Surge Protection Device
TP&SwN	triple pole and switched neutral	LED	Light Emitting Diode
FOC	fiber optic cable	UHF	Ultra High Frequency

8.3.1 HV System

Voltage	33 kV nominal
Phases	3
Frequency	50 Hz
Connection	3 wire
33 kV maximum fault level (breaking capacity)	750 MVA

8.3.2 MV System

Voltage	3.3 KV nominal
Phases	3
Frequency	50 Hz
Connection	3 wire
3.3 KV maximum fault level	200 MVA

8.3.3 LV System

Voltage	415 V nominal
Frequency	50 Hz
Connection	3 phase 4 wire
Off load transformer voltage	433 V
System earthing	TN-S
415 V maximum fault level	25 MVA

8.3.4 **Control Voltage and Instrumentation Power Supply**

Voltage	240 V
Phases	1
Frequency	50 Hz

8.3.5 **PLC Input / Output circuits**

Supply Voltage: 24 V dc

All Plant shall, unless otherwise specified, be capable of continuous operation at a voltage level in the range of 90% to 110% of the relevant nominal voltage and a frequency variation of ±5 % with a maximum combined tolerance of 10%.

8.4 Polarity

The polarity of all apparatus used for the Works specified shall be arranged as follows:

For two pole apparatus the phase or `live' pole at the top (or left hand side) and the neutral or `earthed' pole at the bottom (or right hand side), For three or four pole apparatus the phases in order, red, yellow, blue and neutral reading from top to bottom or left to right in the case of vertical and horizontal layouts, respectively, as viewed from the front.

All cables shall be so connected between main switchboards, distribution boards, plant and accessories so that the correct sequence or phase colours are preserved throughout the system.

All cable cores shall be identified with phase colours for three and four wire circuits. Single phase circuits shall be red and black.

The neutral shall always be black. Where more than one phase is incorporated on a common system in one room then the live cores shall be red, yellow, and blue as appropriate. All fittings and switch accessories shall be permanently labelled and segregated.

8.5 Earthing Arrangements and Protective Conductors

8.5.1 General

Protective earthing conductors shall be provided for all electrical installations and associated mechanical plant, exposed steelwork and buildings.

Protective earthing conductors shall be provided in accordance with the requirements of IS 3043 or equivalent.

8.5.2 **Earthing Conductor**

The electrical installation shall where required be connected to the general mass of the earth by an earthing conductor. The material used for the earthing conductor shall be as follows:

- Conductors above ground shall be galvanised steel tape or conductor
- Conductor buried in the ground or embedded in concrete shall be mild steel; allowance shall be made for reduction in the cross section of the steel over the design life of the earthing system

The earth electrode system shall comprise one or more earth electrodes, earthing tape network, mesh or a combination of these in order to obtain the required earth electrode resistance.

Earth electrodes where used shall be of heavy duty galvanised mild steel of not less than 40 mm NB and 3000 mm long. Where multiple rods are used they shall be separated by a distance of not less than the driven length.

Each earth electrode pipe shall be welded at the top to a mild steel plate to which the earthing tapes shall be connected. These connections shall each be housed in individual concrete inspection chamber set flush to the finished ground level and shall allow disconnection for testing of individual electrodes. The chamber shall be permanently marked `Electrical Earth'.

All materials used for the earth electrode installation shall be purpose made for the application and site conditions and shall be approved by the Engineer.

Unless otherwise stated all excavation for the installation of the earth electrodes and the inspection pit shall be carried out by the Contractor.

After the earth installation has been completed the Contractor shall demonstrate to the Engineer that the resistance of the electrodes to earth and the continuity of the earth network are within the limits specified. Any additional earth electrodes and test instruments required for the tests shall be provided by the Contractor.

Marker posts and plates shall be provided to mark the route of buried tape or conductor electrodes. The markers shall be similar to those provided for cable routes. The requirement for lightning protection shall be checked as per code of practice for lightning protection – IS: 2309 and if found necessary the same shall be provided by the Contractor.

8.5.3 **Main Equipotential Bonding Conductor**

Main equipotential bonding conductors shall be provided to connect the earth electrode system to conductive parts forming the Works.

8.5.4 Circuit Protective Conductors

An independent circuit protective conductor shall be provided for each circuit and may comprise one or any of the following as appropriate:

- a separate core within a multicore cable
- a separate conductor installed within a conduit or trunking
- steel conduit or trunking shall not be used as a circuit protective conductor
- the metal sheath of an armoured cable shall be bonded to the metalwork of the apparatus and to the apparatus earth bar if any
- the copper sheath of a mineral insulated copper sheathed cable
- an independent earthing conductor MS or GS conductor run adjacent to the circuit it protects.

Circuit protective conductors associated with the main circuits supplying switchboards and large electrical loads, i.e. motors in excess of 75 kW shall form a separate core of a multicore cable feeding the device or shall be an independent insulated copper conductor run adjacent to the supply cable. The size of the circuit protective conductor shall be calculated in such a manner as not to take into consideration the contribution of any other parallel or fortuitous earth paths.

The armouring of the supply cable shall not form the sole means of earthing a switchboard or large electrical load.

Where the cable armouring or sheath is used as the circuit protective conductor it shall be securely bonded at both ends to the metalwork of the apparatus and to an earth bar. Particular care shall be taken to ensure continuity across items of apparatus situated within a cable run and should the design of such items of apparatus not give adequate and lasting continuity through its structural body then additional earthing clips and conductors shall be provided to independently bond the cable sheaths together. Similarly additional earthing clips shall be provided to bond the cable sheaths/armour to any piece of apparatus fitted with a special earth terminal should the earth connection for the termination gland be inadequate. Any additional earthing clips shall be fitted within the apparatus wherever possible.

8.5.5 Instrumentation Earth

An instrumentation earth bus shall be provided in each control panel. This shall comprise a copper flat of cross section not less than 25 x 6 mm and length to suit the number of connections. It shall be mounted on at least two insulated supports and be provided with a single earth connection to the control panel electrical power earth. If due to the physical size of a control panel more than one instrument earth bar is required the additional bar shall be connected again with a single earth connection to the same point as before on the control panel electrical earth bar. In this fashion all instrument earths shall be connected radially from the same earth point.

All signal cable screens (analogue and digital) shall be terminated onto the instrument earth bar. Signal cable screens shall be earthed at the control panel end only. Screens at the field end shall be tied back and insulated.

SPD's associated with the control and instrumentation system shall be earthed to the instrument earth in accordance with the SPD manufacturer's recommendations.

8.6 Cables and Wires

8.6.1 General

Each drum or coil of cable shall be accompanied by a certificate stating the manufacturer's name, cable size, number of cores, length, result and date of tests as required in the Employer's Requirements.

Cables manufactured more than 12 months before delivery shall not be accepted.

All cables shall be delivered with cable ends effectively sealed. When a cable is cut from a drum both ends shall be immediately sealed to prevent ingress of moisture.

Cables shall not be transported to site in loose coils but a number of short lengths of cable may be transported on the same drum. The Contractor shall be wholly responsible for the purchase and/or hire costs of all cable drums and for the removal of these drums from site after use.

HV / MV / LV Cables shall comply with the following International Standards, including those referred to therein.
IEC 60183, 60227, 60502, 60885 and IS 7098, 5831, 8130, 1554, 10810.

The technical parameters of cables shall be as given below:

Description	Unit	Particulars
HV and MV XLPE Power Cables		
Rated voltage U / Uo (Um)	kV	18 / 30 (36) and 3.6 / 6 / (7.2)
Material of conductor		Aluminium (stranded)
Cross-sectional area		(*)
Type of insulation		XLPE
Inner sheath		Extruded
Outer sheath		Extruded
Conductor and insulation screening		Required
Material of armour		Galvanized Steel (Aluminium for single core cable)
LV Power, Control and Lighting Cables		
Rated voltage U / Uo (Um)	kV	0.6 / 1 (1.2)

Description	Unit	Particulars
Material of conductor		Aluminium for Power and Tinned Copper for Control cable (stranded)
Cross-sectional area		(*)
Type of insulation		XLPE for power and PVC for control cables
Inner sheath		Extruded
Outer sheath		Extruded
Material of armour		Galvanized Steel (Aluminium for single core cable)
Cable Protection		Compound of outer sheath of all HV/MV/LV cables shall contain suitable chemicals for preventing attack by rodents.

(*) Value to be ascertained by the Contractor after submitting design calculations subject to approval.

Control cables shall be 2C, 4C, 7C, 12C and 19C type. Minimum size of conductor for control cables shall be 2.5 sq.mm. Copper.

All power cables shall be sized based on continuous current capacity, maximum permissible voltage drop of 3% and rated short circuit current withstand. In addition, rating factors for variation in ground/air temperature, grouping of cables, depth of laying, number of racks, etc. shall be considered for cable sizing.

8.6.1.1 *Tests*

All HV, MV and LV cables shall be subject to routine tests in accordance with the relevant Indian Standard Specifications.

Test certificates shall be provided against each drum and/or cable length.

The tests carried out on every cable length and / or drum at manufacturer's premises shall include following tests as applicable but not limited to:

- high voltage dc insulation pressure test, between cores, each core to earth, metallic sheath or armour as applicable;
- insulation resistance test;
- core continuity and identification;
- conductor resistance test
- Elongation test
- Smoke density test
- HCl gas generation test
- Anti rodent test (Presence of lead)

8.6.1.2 *Telecommunications*

External Use

The cable shall be cellular polyethylene insulated armoured telephone cable manufactured generally in accordance with Indian Department of Telecommunications Specifications. The conductors shall be 0.9 mm diameter copper. The insulated conductors shall be twisted together in pairs and shall be identified by colour. The cable shall be fully filled with tropical grade petroleum jelly and a polyethylene sheath shall be applied over the laid up pairs. A layer of galvanised steel wires shall be applied over this sheath.

A black coloured PVC or polyethylene sheath shall be applied overall.

Installed in ducts, pipe ducts and direct in the ground.

Internal Use

The cable shall have tinned copper conductors of 0.5 mm diameter with PVC insulation and PVC oversheath. It shall comply generally with Indian Department of Telecommunications Specifications.

The colour of the sheath shall be cream.

For use indoors for internal distribution and connection to extension instruments, cables shall be installed in conduit, trunking or clipped direct.

8.6.1.3 *Instrumentation*

Contractor shall include in his scope the supply and laying of instrumentation signal and instrument power supply cables and associated civil / mechanical work required for completing the system.

Cables shall be capable of satisfactorily withstanding without damage, transportation to site, installation at site, and operation under normal and short circuit conditions of the various systems to which the respective cables are connected when operating under the climatic conditions prevailing at the site as indicated in this specification.

Cable joints in instrument signals and power supply cables shall not be permitted.

Cables shall be capable of satisfactory performance when laid on trays, in trenches, conduits, ducts and when directly buried in the ground.

Cables shall be capable of operating satisfactorily under a power supply system voltage variation of ±10%, a frequency variation of ±5.0%.

a) Cables for Digital Signals

660V/1100 V grade multicore cables, multistranded high conductivity annealed 1.0 sq.mm stranded tinned copper conductor, extruded PVC insulated, overall screened with braided wire or with aluminium mylar tape, ATC drain wire run continuously in contact with aluminium tape, inner sheathed with extruded PVC, armoured with galvanized steel wire overall sheathed with extruded PVC conforming to IS:1554 and IEC:189 Part II.

b) Cables for Analog Signals

660 V/1100 V annealed, tinned, high conductivity 1.0 sqmm stranded copper conductor extruded PVC insulated two/ three cores twisted into pair/ triad, laid up collectively, individual pair/ triad shielded and overall shielded with wire braiding or aluminium mylar tape, ATC drain wire run continuously in contact with aluminium side of the tape, inner sheathed with extruded PVC, armoured with galvanized steel wire, overall sheathed with extruded PVC conforming to IS:1554 and IEC:189 Part II.

8.6.1.4 *SCADA System*

Fiber optic cable shall be applied to the SCADA system to integrate PLCs located at each local control room and operator stations located at the SCADA room. FOC shall be single mode, glass made core and clad and PVC covered with tension member, jelly filled and PVC sheathed. Maximum attenuation of OFC shall be 0.4 dB/k m and 0.3 dB/km at 1310nm and 1550nm wave length light respectively. FOC shall be installed in HDPE conduits including all accessories like couplers, etc for underground installations.

8.6.2 **Cable Rating**

The Contractor shall ensure that cable and wires associated with the distribution and control systems, plant wiring and all other installations throughout the Works are adequately rated for their use.

In assessing the rating of any cable or wire, the following factors shall be taken into account:

- **Supply voltage and frequency**
- **Maximum voltage drop permissible**
- **Type and magnitude of load**
- **Fault level and duration related to circuit protection relays and fuses**
- **Circuit over current protection**
- **Route length and disposition of cables**
- **Ambient temperature**
- **Method of installation**

All power cables shall be sized for continuous current carrying capacity at the ambient temperature of 50 ^{0}C. The design current of any circuit shall exceed the full load current of the supplied device by at least 10%. Power cables shall be sized to limit the maximum voltage drop to no more than 3 %.

Under motor starting conditions the corresponding voltage drop shall not affect the operation of the motor controls or the ability of the motor to start and run effectively and in any event shall not exceed 10%. While sizing cables for the remote operation of shunt trip coils the contractor shall take due account of the voltage drop caused by the momentary current surge taken at the instant of energisation.

8.6.3 **Cable Colors**

All cable cores shall be colour coded throughout their length and shall be so connected between switchboard, distribution board, plant and accessories, that the correct sequence or phase colours are preserved throughout the system.

The colour coding should be as follows:

3 phase	red, yellow and blue
single phase or dc	red and black
earth	green/yellow
control	blue (dc), red (ac)

8.6.4 **Cable Conductors**

Copper conductors shall be used throughout. Cores of cross-sectional area greater than 1.5 mm^2 shall be stranded.

Lighting final distribution circuits shall be of a minimum cross-section of 1.5 mm^2. Small power and control cables shall be of a minimum cross-section of 2.5 mm^2.

Internal wiring of control panels shall be of a minimum cross-section of 1.0 mm^2 flexible and stranded.

Instrumentation and control cabling shall be of a minimum cross-section 1.0 mm^2 .

HV/ MV and LV cables shall be sized as a minimum for a fault clearance time of 0.5 seconds for the incoming feeders and 0.16 seconds for switchboard feeders controlled by circuit breaker.

8.6.5 **Cable Numbering**

All cables shall be allocated a unique number which shall be fixed to each end of the cable using a corrosion resistant label. Cables of different categories shall be tagged with the following subscripts and three digit numbers.

HV power	HV-P_ _ _
MV power	MV-P_ _ _
LV power	P_ _ _
Control	C_ _ _
Instrumentation	I_ _ _
Protection	PR_ _ _

Telecommunication T_ _ _

8.7 Cable Installation

8.7.1 General

All outdoor and indoor cables shall be installed in cable trenches in such a way that the minimum bending radii are not reduced when installed or during installation. Cables shall not be installed in ambient temperatures below that recommended by the cable manufacturer.

Cables grouped together shall have insulation capable of withstanding the highest voltage present in the group.

Cables of different categories shall be installed so as to maintain satisfactory clearances for safety and in order to reduce the possibility of electrical interference. The following Table details the distances in mm that shall be maintained between the different categories of cable. The following table shows Separation Distances in mm between different Categories of Cable.

Cable Category	HV Power	MV Power	LV Power	C&I/Protection	Telecommunication
HV Power	N/A	300	300	500	500
MV Power	300	N/A	300	300	300
LV Power	300	300	N/A	300	300
C&I/Protection	500	300	300	N/A	100
Telecommunication	500	300	300	100	N/A

These separations are minimum and special circumstances such as the presence of high current flows, or harmonic content may necessitate larger separation distances.

In order to make economic use of the cable support system, cables shall be arranged in groups of 50 mm maximum overall diameter. These groups shall be securely tied to the cable support system at intervals not exceeding 900 mm for horizontal runs and 300 mm intervals on vertical runs.

Cables shall be laid in a manner such that any electrical interference between cables shall not have a detrimental effect on the life and operation of Plant.

A separate cable support system shall be provided for power and non-power cables. Where this is not practical a separation of 150 mm shall be maintained between power and non-power cables when run on the same support system.

Heavy duty galvanised iron cable tray and ladder racking shall be used for cable support systems. Plastic or GRP cable support systems shall be used in areas used for the storage and handling of chlorine. These systems shall be used to route cables around walls and within cable trenches. Cables shall be securely fixed to the support systems. Bundling of cables shall be permitted where allowance for this practice has been made in sizing the cables.

8.7.2 Instrumentation Cabling

In order to make the most economic use of cable ladder/tray and duct capacity, multicore cabling shall be utilised in order to connect instrumentation groups by using suitably located sub-distribution junction boxes. The junction boxes shall be suitable for the area in which they are to be installed and for the type of circuit. They shall be readily accessible for maintenance and clearly labelled junction boxes shall be constructed of die cast aluminium and provide degree of protection IP 65.

Separate cables shall be used for digital and analogue signals at all times.

Instrumentation cables shall be continuous without any joints.

Digital and analogue signals shall be segregated within junction boxes.

8.7.3 Cables Laid Direct in Ground

Buried cable up to 650/1100 V shall have a minimum cover of 500 mm measured to the top of the highest cable. On crossing roadways the cable shall be run through a GI pipe of minimum diameter 100 mm with a minimum of 1000 mm cover and encased on all sides by 150 mm of concrete.

Cables of greater than 650/1100 V shall be buried with a minimum cover of 1 m.

The bottom of the cable trench shall be freed of sharp stones and such like and 75 mm of sieved sand laid below the cable. After cable laying 75 mm of sieved sand shall be laid above the cable.

Interlocking cable protective covers, minimum 1 m long x 300 mm wide, marked `Danger - Electric Cable' in English and the vernacular shall be laid on top of the sieved sand. Covers shall extend the whole length of the cable trench and shall overlap cables by a minimum of 50 mm.

Warning tape shall be laid a minimum of 200 mm above the protective covers.

Single core cables shall be run in trefoil formation.

8.7.4 Cables installed in Conduit

8.7.4.1 *General*

Conduits shall be galvanised heavy gauge solid drawn or welded screwed steel type and be in accordance with IS 9537 Part 2 or BS 4568. Accessories shall either be malleable cast iron screwed type or pressed steel and galvanised.

A space factor of 40% shall not be exceeded, but in any case conduit of less than 20 mm diameter shall not be permitted. The tubing shall be perfectly smooth inside and out and free from flaws and imperfections of any kind. Both ends of every length of tubing shall be properly reamed with all sharp edges removed before erection.

Where a number of conduits converge, malleable cast iron or heavy gauge sheet steel adaptable boxes shall be employed in order to avoid crossings. Conduits shall be connected by means of male brass bushes and couplings.

Where conduits are greater than 25 mm, straight through joint boxes shall be of the trough type. Where conduit and/or fittings are attached to equipment casings, the material or case of the casing shall be tapped for a depth of not less than 10 mm or male bushes and flanged couplings shall be used.

Heavy hexagonal lock nuts shall be used at all positions where running joints are required and great care shall be taken to ensure that they seat firmly and evenly on to the mating faces of coupling or other adjacent accessories. All junction boxes, draw-in boxes, and inspection fittings, shall be so placed that the cables can be inspected and, if necessary, withdrawn and re-wired throughout the life of the installation.

Generally not more than two bends or offsets or one coupling will be permitted without a suitable inspection accessory. Fish wires shall not be left in conduits after erection. The whole of the installation shall be arranged for a loop-in type of system with joints being carried out at switches, isolators, etc. Intermediate joints in the cable will only be allowed by arrangement with the Engineer. Where terminal blocks are necessary, they shall be of the porcelain type with brass pinching screws.

Ends of conduits which are liable to be left open for any length of time during building operations shall be plugged to prevent the ingress of dirt, cement, etc. and covers, either temporary or permanent, shall be fitted on all boxes.

Generally, conduits shall not cross expansion joints of buildings, but where they cannot be installed in any other manner then a flexible conduit shall be used across the expansion joint. A total 150 mm movement shall be allowed.

8.7.4.2 *Surface Installation*

Surface conduits shall be secured and fixed by means of distance spacing saddles or approved purpose made clips which allow the conduits to be taken directly into accessories without sets or bends. Conduits shall be run in a square and symmetrical manner. An efficient means shall be adopted to provide for the drainage of condensation and the runs shall be properly ventilated. All surface conduit runs shall be marked out for approval by the Engineer before the installation is carried out. Where large multiple parallel conduit runs would occur, use may be made of galvanised cable trunking. Conduits installed on structural steelwork shall be secured at spacings not exceeding those for surface conduit by girder clips, otherwise fixing shall be as for surface conduits on walls, drilled and tapped to the metalwork. Power driven fixings shall only be used with the express permission of the Engineer. Any drilling or access which is required through any structural member of the building shall be agreed with the Engineer before carrying out the work.

Exposed threads and places where galvanising has been damaged shall be cleaned and then painted with two coats of an approved metallic zinc based paint. This treatment shall be applied as the work proceeds.

8.7.4.3 *Concealed Installation*

Concealed conduits shall be securely fixed to prevent movement before laying of screeds, floating of plaster, casting of columns or other building operations necessary after the conduit installation. Crampets or similar fixings shall be used for attaching the conduit to blockwork, etc. Building nails will not be accepted.

At least 15 mm cover shall be allowed for finishes over the conduit. Where this cover cannot be maintained then expanded metal shall be fitted with the conduit. Conduit cast into reinforced concrete floors shall be fixed to the steel reinforcing with binding wire and the conduit boxes filled with expanded polystyrene or enclosed in a plastic bag to prevent the ingress of concrete when poured. Where possible, the conduit boxes shall be fixed to shuttering to give a flush finish.

Conduit installed in voids, false ceilings, and other concealed routes shall be installed as specified for the surface conduits. Wiring shall be carried out after the false ceiling or permanent ducts have been completed. Conduit installed in floors shall be sealed against ingress of moisture.

The conduit installation shall be inspected and approved by the Engineer before the building operation conceals the work.

8.7.4.4 *Cable Installed in Flexible Conduit*

Flexible conduit shall be of the waterproof galvanised type or PVC wire-wound type with cadmium plated mild steel couplings. Lengths of flexible conduits shall be sufficient to permit withdrawal, adjustment or movement of the equipment to which it is attached and shall have a minimum length of 300 mm. Flexible conduit shall not be used as a means of providing earth continuity. A single earth conductor of adequate size shall be installed external to the conduit complete with earth terminations.

Where conversion from rigid conduit to flexible metallic conduit is to be made, the rigid conduit shall terminate in a through type box and the flexible conduit shall extend from this box to the equipment, the earth continuity cable shall be secured to the box and to the piece of equipment by properly designed earthing screws. The use of lid facing screws, etc., shall not be permitted. Adapters shall incorporate a grub screw or a gland to prevent the flexible conduit becoming loose.

8.7.4.5 *Cable Installed on Cable Tray*

Cable tray shall be of perforated sheet steel with formed flanges and of minimum thickness not less than 1 mm for trays up to 100 mm width, not less than 1.25 mm for trays from 100 mm to 150 mm width and not less than 1.5 mm for trays from 150 mm to 300 mm width and not less than 2 mm for trays from 300 mm to 600 mm width.

Cable tray shall be hot dipped galvanised. Cable tray for use in areas where chlorine gas may be present shall be constructed from U-PVC or GRP. Cable tray supports shall be of a compatible finish with the associated cable tray.

All cable tray tees, intersection units, bends, turns and sets shall be purpose made by the manufacturer and shall be of a matching design to the main section of cable tray.

Tray shall only be joined by couplers supplied by the manufacturers. The joint shall be secured in accordance with the manufacturer's instructions.

Cable tray supports supplied by a manufacturer or made up on Site shall be of ample strength to maintain rigid support to the fully laden cable tray along its entire length and shall ensure that the deflection of any one section does not exceed 15 mm at mid-span.

Wherever possible, cable trays shall be installed in full lengths without cutting. Should it be necessary to cut or drill a length of tray, then for galvanised trays, the bared ends or damaged section of the tray shall immediately be given a coat of zinc rich cold galvanised paint. All site manufactured accessories, supports and metal fittings required to ensure correct installation of the cable trays shall be similarly treated.

All cables shall be firmly secured to the tray using purpose made saddles, as approved by the Engineer, together with proprietary nylon fasteners and/or cable cleats. Following installation of cables, the tray shall remain rigidly supported and the deflection of any section shall not exceed 15 mm at mid-span. All brackets and tray work shall be suitable for withstanding a temporary weight of 125 kg.

Cable trays shall not be cut to allow the passage of cables through the surfaces of the tray.

The sizing of the cable tray shall provide a minimum of 25% spare capacity.

The tray shall be run at least 150 mm clear of plumbing and mechanical services.

8.7.4.6 *Cable Installed on Ladder Rack Systems*

Ladder racking either light or heavy weight shall be proprietary item and installed in accordance with manufacturer's instructions. Bends in the installation shall take account of the minimum bending radii of cables to be installed.

Cables shall be clipped to the ladder rack using clips designed for the system in use and appropriate to the type and size of cable installed.

The sizing of the cable rack system shall provide a minimum of 25% spare capacity.

The ladder racking shall be run at least 150 mm clear of plumbing and mechanical services.

8.7.4.7 *Cable Clipped Direct*

All cable hangers, clips, cleats and saddles shall be of an approved type and appropriate to the type and size of cable installed.

Their spacing shall be such as to ensure a neat appearance and prevent sagging of the cables at all times during their installed life.

8.7.4.8 *Cable Installed in Internal Floor Trench*

In Shallow trenches (maximum depth 500 mm)

In shallow trenches used for electrical services only, cables may be laid in a neat and orderly manner on the floor of the trench. One layer only shall be allowed. Additional cables shall be installed on the walls of the trench in an approved manner. Where the trench is shared by other services, cables shall be installed on the walls of the trench in an approved manner.

All other trenches including walk through service ducts

Cabling shall be installed to the walls of the trench in an approved manner. Where other services are present the cables shall be segregated from them and wherever possible kept above `cold' wet services. Cables should not be run if at all possible above or in close proximity to `hot' services. The cabling shall be installed in such a manner as to allow access to the other services for normal maintenance without disturbance of the electrical installation

8.7.5 **Cable Terminations and Joints**

8.7.5.1 *Power Cable Terminations*

Power cables shall be terminated in suitable boxes arranged for bolting to switchgear, motor starters and motors.

Cores shall have either crimped lugs or sleeves to match either post terminals or bolted clamp terminals.

Each cable entry into a terminating box shall be made through a suitable gland, which shall have provision for securing the armour where applicable. Where single core glands are required these shall be of the non-magnetic type and the associated box bottom plate, where the core passes through, shall not have a continuous magnetic path.

Adequate provision shall be made to bond the cable armouring to the box and/or switchgear casing of a suitable size to withstand the prospective short circuit fault current of the system, glands shall be fitted with earth bonding tags where intimate screwed contact between gland and cable box is not possible.

Where cable glands are exposed to the weather these shall be protected by heat shrink plastic sleeve or purpose moulded sleeves covering the gland continuously from overall sheath to the gland neck.

Where terminations of multicore type have to be made on to items of Plant which have to be dismantled for maintenance, these shall be made off through glands into an adaptable box containing terminals and flexible single cores taken into the equipment via flexible waterproof plastic covered conduit, and a separate earth core linking the box to the equipment.

Where single core cables are glanded to or pass through cabling plates the gland plate or cabling plate shall be constructed of non-magnetic material.

8.7.5.2 *Multicore or Control Cable Terminations*

A sufficient number of terminals shall be provided to terminate all cable cores. For control and auxiliary wiring an additional 20% of this number shall be provided as spares.

Not more than one core of internal or external wiring shall be connected on any one terminal. Where duplication of terminal blocks is necessary, purpose-made solid links shall be incorporated in the design of the terminal blocks.

Terminals which remain energised when the main equipment is isolated shall be suitably screened and labelled.

Terminal blocks for different voltages or circuit type shall be segregated into groups and distinctively labelled.

8.7.5.3 *Cable Fixings*

Suitable Ties and strapping shall be used for securing cable and cable groups to cable tray or ladder. They shall be resistant to chemical and marine corrosion. Plastic coated metal ties used in order to obtain corrosion resistance shall not be acceptable. Nylon ties shall be resistant to the effects of ultra-violet light and shall be self-extinguishing. Large single cables shall be secured with cable clamps or cable cleats.

8.7.5.4 *Cable Identification*

At each end of each cable, in a uniform and visible position a label shall be fixed on the cable in accordance with the cable schedule. Labels shall be made of PVC and shall be indelibly marked to the approval of the Engineer. The label shall be retained using proprietary nylon strips passing through two fixing holes at either end of the label. If the cable gland is not normally visible, then the label shall be fixed inside the panel by means of screws.

8.7.5.5 *Cable Glands*

Glands shall generally be of the mechanical compression hexagon type. Earth continuity of brass glands shall be assured. This may be achieved by the rigid clamping of the armour within the gland and the intimate contact between the threaded components of the gland and the equipment. Each gland shall be installed complete with proprietary earth tag providing a ready means of connecting a flexible strand or strip earth bond to the gland at any position around the gland in relation to the associated apparatus. Adequate earth continuity shall be assured between the earth tag, the gland and the armour wires of the cable where applicable.

Glands for single core cables shall be constructed from non-magnetic materials.

Each gland shall be installed complete with a proprietary non-ferrous lock-nut to secure the gland body to the equipment where the entry hole is plain, i.e. not tapped.

Where holes for cable entries are not provided it shall be the responsibility of the Contractor to mark out and drill such holes. Burrs and swarf shall be removed, care being taken to ensure that swarf and filings, etc do not enter the equipment.

For non-hazardous areas cable glands in situations where moisture may be present shall be double seal weatherproof type, gland shrouds shall be used and entry shall be sealed.

For dry indoor situations, standard industrial glands with shrouds are acceptable.

For hazardous areas, glands conforming to EExd standard shall be used with double seal and shroud.

Power cable glanding arrangements in hazardous areas shall incorporate an insulated adapter and earth link. This shall provide the facility to disconnect the armouring from the glanded device in order that a true earth loop value may be measured when carrying out tests on the installation.

8.7.6 **Marking Locations of Underground Cables**

The location of all underground cables shall be engraved on brass or other non-corrodible plates to be fixed to the exterior surface of all walls of buildings 300 mm above ground level and directly above the point where cables pass through the wall.

In addition concrete marker posts shall be installed at intervals of not more than 50 m at all junctions and changes of direction along the cable route. Such marker posts shall be not less than 200 mm high and of substantial construction. A drawing or sample of a typical marker post shall be submitted for the approval of the Engineer.

The markers shall be marked `electric cable' in English and the vernacular.

8.7.7 **Fire Proof Sealing (FPS) System**

Fire proof sealing system shall be provided and shall consist of

a) Fire-stops / fire-seals for sealing of cable / cable tray and conduit / pipe penetrations, both horizontal and vertical, through brick or RCC walls / floors, to prevent the spread of fire from one area to other areas by fire-resistant barriers.

The FPS system shall also include all the necessary accessories and equipment required for supporting, holding in position, fixing and installation of the fire-stop.

The FPS system shall comply in all respects with the requirements of the codes and standards mentioned herein IEC-331 and IEC-332.

Fire Stop / Seal

The FPS system adopted for cables or cable trays penetrating through walls and floor openings, or cables passing through embedded conduits / pipes / pipe-sleeves, constitutes a `fire stop / seal', which is meant to prevent spreading of fire between areas separated by fire-resistant barriers.

Performance Requirements

Requirement of fire stops

i. The material, design and construction of the fire stops shall be such as to provide a fire-rating of 120 minutes for a fire on any side and meet all requirements listed in this specification and the relevant codes and standards.

ii. The materials used in the fire stops shall be non-hygroscopic, compatible with the type of cables.

iii. The fire stops shall be suitable for retrofitting of cables through the penetration seal without disturbing the sealing of the cables already existing.

Application of Fire Proof Sealing System

a) Fire stops

Fire stops shall be provided for cable penetration openings listed below

  i. The passage of cables / cable trays pipe sleeves / embedded conduits through walls / floors.

  ii. Vertical raceways, if any, which carry cables between successive floors, through openings provided in the RCC floor slab, shall be sealed by fire stops at each floor level.

  iii. Cable entry through openings in floor slabs.

Contractor shall furnish the test certificates for the fire stops after award of Contract for Employer's Representative review. If the certificates are not satisfactory, all the tests shall be conducted free of cost. The offered system i.e. fire stops and fire breaks shall be identical (or better) with the system which is successfully type tested for the specified rating i.e. the composition density of the material, thickness of coating in case of fire breaks and any other properties of the material / system offered shall be identical or better than the tested system and shall be subject to Employer's Representative approval.

Performance Tests:

a) The fire stops shall be subjected to the following type tests:

  i. Fire Rating Test

  ii. Hose Stream Test

b) Type tests shall be conducted on different fire stop test specimens described above as per IEEE-634. The sizes of the fire stop test specimens shall be similar to the largest of the sizes being used in the plant.

c) Preconditioning of fire stop test specimens

Before conducting the Fire Rating and Hose Stream tests, each test specimen shall be preconditioned for thermal ageing, water immersion and vibration.

d) Test on Fire Stops

During the Fire Rating test, the transmission of heat through the cable penetration fire stop shall not raise the temperature on its unexposed surface above the self ignition temperature of the outer cable covering, the cable penetration fire stop material, or material in contact with the cable penetration fire stop, with a maximum temperature limit on the unexposed surface of 200^{0}C.

8.8 Power Transformers

8.8.1 General

Transformers shall comply with IS 2026, BS 171 or IEC 76. They shall be oil immersed, naturally cooled type classified ONAN for pole and ground mounting.

The transformer shall be sized for continuous operation at its maximum rating under the climatic conditions defined in the Employer's Requirements. Unless otherwise stated, the rating shall allow for unshaded conditions.

The load factor shall be taken as 80% for normal operation.

8.8.2 Construction

The transformer tank shall be made from high-grade sheet steel, suitably reinforced by stiffeners made of structural steel sections. All seams, flanges, lifting lugs, braces, and other parts attached to the tank shall be welded. The interior of the tank shall be cleaned by shot blasting and painted with two coats of heat resistant, oil insoluble paint. Adequately sized manholes shall be provided for ease of inspection and maintenance. Steel bolts and nuts exposed to atmosphere, shall be galvanised. The tank cover shall be removable and shall be suitably sloped so that it does not retain rainwater.

Lifting lugs and eyebolts shall be so located that a safe clearance is obtained without the use of a spreader, between the sling and transformer bushings.

Transformers shall be provided with fixed type radiators. Fins of the radiators shall not have sharp edges and shall be rounded in shape.

The transformer core shall be constructed from high grade, non-ageing, cold-rolled, grain oriented, silicon steel laminations. The steel laminations shall be of "core" type. Each lamination shall be coated with insulation which is unaffected by the temperature attained by the transformer during service. Core laminations shall be annealed and burrs removed after cutting. Cut edges shall be insulated. The framework and clamping arrangements of core and coil shall be securely earthed inside the tank by a copper strap connection to the tank.

Windings shall be of insulated copper wire or copper strip. Windings and insulation shall be so arranged that free circulation of oil is possible between coils, between windings, and between winding and core. The windings shall be fully shrunk under vacuum before assembly. High voltage end-windings shall be suitably braced to withstand short circuit stresses and stresses caused up by surges.

The sequence and orientation of HV/LV side phase and neutral bushings shall be as specified in the latest edition of relevant IS.

Transformer shall operate without injurious heating at the rated KVA and at any voltage up to + 10 % of the rated voltage of any tap. Transformer shall be designed for 110 % continuous over-fluxing withstand capability.

Noise level of the transformer shall be less than 80 dB.

8.8.3 **Windings**

Windings shall be double wound Group IV, vector group Dyn 11. ON load tap changing shall be provided with tapings from ±10% in steps of 1.25 %. It shall be possible to padlock the tap changing handle to prevent unauthorised operation. Tap changing on pole mounted transformers may be carried out by links.

8.8.4 **Tank Fittings**

Transformers will be located outdoor and shall also be rated for satisfactory operation at 50^0C design ambient temperature.

Each main power transformer shall have the following fittings and accessories including but not limited to:

a) A conservator of sufficient volume with:

   i. separate compartment for OLTC (Alternatively a separate conservator for OLTC)

   ii. oil level gauge with potential free contacts for initiating alarm for low oil level

   iii. weather-proof dehydrating breathers for both compartments with activated alumina or silica gel as the dehydrating breather

   iv. shut off valves

   v. filling plug and drain valves

The conservator shall be designed to maintain an oil seal upto a temperature of 100^0 C.

b) Gas and oil actuated Buchholz relay with

   i. necessary shut off valves

   ii. test cock with pipe connections for sampling

   iii. potential free contacts for initiation of alarm in case of slow gas formation and trip in case of fast oil and gas surges

c) Separate Buchholz relay as in b) above for OLTC chamber of conservator

d) Dial type thermometer with

    i. maximum temperature indicator and its resetting device
    ii. potential free contacts for initiating alarm on high temperature and trip on very high temperature

e) Winding temperature indicator with

    i. necessary sensing, compensating and calibrating devices
    ii. potential free contacts for initiating alarm on high temperature and trip on very high temperature
    iii. WTI transmitter for remote indication on remote tap changing panel

f) Detachable type of radiators including but not limited to:

    i. Shut-off valves and blanking plates on transformer tank at each point of connection of inlet and outlet header
    ii. Top and bottom shut-off valves and blanking plate on each radiator
    iii. Lifting lugs
    iv. Top oil filling plug, 19 mm size
    v. Air release plug at top
    vi. Oil drain plug at bottom, 19 mm size
    vii. Earthing terminals

g) Pressure relief device for transformer tank and OLTC

h) Weather - proof marshalling box mounted on transformer tank

i) Name plate, rating plate and Diagram plate

j) Valves and plugs as below:

    i. Drain valve
    ii. Filter valve
    iii. Oil sampling valves at top and bottom
    iv. Valves between radiators and tank (in case of detachable radiators)
    v. Air release plug
    vi. Twin outlets (with plug) for applying vacuum with attachments.

k) Earthing pads of copper or non-corrodible material for transformer tank (2 places) and radiator banks

l) Inspection manholes as required

m) Lifting arrangement for

    i. fully assembled transformer
    ii. core and coil

iii. tank

n) Hauling eyes on each face of the transformer

o) Bi-directional flanged wheels

p) Anti-earthquake clamping devices

q) Jacking pads

Each auxiliary transformer shall have the following fittings and accessories including, but not limited to:

a) Conservator with oil level gauge

b) Dehydrating silica gel breather

c) Oil temperature indicator

d) Thermometer pocket

e) Explosion vent diaphragm / pressure relief valve

f) Sampling and drainage valves

g) A plug or blank flange at the top for connecting valve for filtration

h) Two earthing terminals

i) Rating plate (Name plate and diagram plate)

j) Lifting lugs

k) Removable plain rollers

l) Adequate number of air vents for relieving trapped air during oil filling and during maintenance.

m) Accessories for clamping the wheel to the foundation channel in order to withstand earthquake forces.

All switching devices shall be provided with alarm and tripping contacts. The contacts shall be rated for the specified application.

8.8.5 **Transformer Oil**

Transformer oil shall comply with IS 335, BS 148 or IEC 296.

8.8.6 **Cable Terminations**

Cable termination boxes for ground-mounted transformers shall be suitable for dry termination of HV and LV cables. Non-magnetic gland plates shall be provided for the termination of single core cables.

It shall be possible to remove the cable boxes without dismantling the cable glanding or draining the oil. Disconnecting links shall be provided to facilitate testing of the cable.

8.8.7 Tolerance on Losses

The permissible tolerances on the guaranteed values of transformer losses shall be as per IS 2026. The values of load- losses and No-load losses shall be within the values given in latest edition of CBIP manual for transformers.

8.8.8 Technical Particulars of Transformers

Description	Unit	Particulars	
General			
Quantity required		Main Transformer	Auxiliary Transformer
		2 nos. each of 33/3.3kV	4 nos. each of 3.3 /0.433kV
Installation (Indoor / Outdoor)		Outdoor	
Ratings			
Rated power		Main Transformer	Auxiliary Transformer
(*) Contractor shall submit their design calculation for rating of each equipment for purchaser Representative's approval.	kVA	*(*)- for* (8VT CWPS) for 100% final load	(*) (8VT CWPS) (*) (Golkamra CWPS)
No load voltage Primary	kV	33	3.3
Secondary	kV	3.3	0.433
Number of phases		3	
Rated frequency	Hz	50	
Impedance voltage	%	As per IEC/BIS	
Vector group		Dyn11	
Winding material		Electric Grade Copper	
Type of cooling		ONAN	
System Voltage			
Nominal system voltage Primary	kV	33	3.3
Secondary	kV	3.3	0.415
Highest system voltage - Primary	kV	36	7.2
- Secondary	kV	7.2	1.2
Transformer Secondary Neutral Earthing		Earthed through resistance to limit	Effectively earthed

Description	Unit	Particulars	
		the earth fault current to 1000 A subject to approval	
Insulation Withstand			
Rated lightning impulse withstand voltage	kV (peak)	170	40
Rated short duration induced or separate source AC withstand voltage - Primary	kV (rms)	70	10
- Secondary	kV (rms)	10	3.5
Temperature Rise			
Reference design ambient	^{0}C	50	
Temperature rise over design ambient temperature of 50 ^{0}C			
- Average winding temperature rise (by resistance measurement)	^{0}C	55	
- Top oil temperature rise (by thermometer)	^{0}C	50	
Tap Changing Gear			
Type of tap changer		On Load Tap Changer	Off Circuit tap Changer
Tapping range	%	± 10%	± 10%
Tapping steps	%	1.25	2.5
Bushings			
Rated voltage – Primary	kV	36	7.2
– Secondary	kV	7.2	1.2
One minute power frequency withstand voltage (dry and wet) – Primary	kV (rms)	70	10
- Secondary (Line and Neutral)	kV (rms)	10	3.3
Rated lightning impulse withstand voltage	kV (peak)	170	40
Nominal creepage distance	mm/kV	31	
Terminal Connections			

Description	Unit	Particulars	
Primary line end		Cable box	Cable box
Secondary line end		Cable box	Cable box OR Bus Duct Flange
Secondary neutral end		Bushing outside cable box	One bushing each inside and outside cable box
Type of wheels		Bi-direction, Flanged – Rail mounted	Plain – Bi-directional
Cable sizes:			
- Primary		18 / 30 (36) kV, (*)sq. mm. aluminum, XLPE, screened, armoured cable	3.6 / 6 / (7.2) kV, (*) sq. mm. aluminum, XLPE, screened, armoured cable
- Secondary		3.6 / 6 / (7.2) kV, 3Cx (*) sq. mm. aluminum, XLPE, screened, armoured, cable **OR** 1C x (*) sq. mm. (per phase) aluminum, XLPE, screened, armoured cable	0.6 / 1 (1.2) kV, 3.5Cx (*) sq. mm. aluminum, XLPE, armoured cables or bus -duct
Accessories		OTI, WTI, MOG, Buchholz relay, Pressure relief valve, conservator, pressure relief device on OLTC	OTI, WTI, MOG, Buchholz relay, conservator

(*) Values to be ascertained by the Contractor after Submitting design calculations subject to approval.

8.8.9 Tap Changing Gear

8.8.9.1 *On-Load Tap Changer (OLTC):*

a) OLTC gear shall safely carry and withstand through fault current of the transformer and shall incorporate protections to prevent tap change operation during flow of such fault current.

b) Tap changing once initiated should be completed irrespective of status of the initiating devices or loss of control supply.

c) OLTC gear shall have separate conservator connections and Buchholz relay so that the oil of OLTC does not mix with transformer oil. Alternately, OLTC shall have a separate conservator with accessories.

d) Provision shall be available for filling, draining of the oil, release of air, etc.

e) OLTC driving mechanism and its associated control equipment shall be mounted in a weatherproof cabinet having degree of protection of at least IP65. The cabinet shall incorporate the following:

i. Driving motor with associated switch and fuse (or MCB) and raise and lower contactors with overload and single phasing protection
ii. Remote / local selector switch
iii. Control switch for raise / lower operations
iv. Pressure relief device and pressure relay
v. Over current blocking device
vi. Parallel control device
vii. Limit switches to prevent over travel and final mechanical stops
viii. Manual operating device with interlocking switch
ix. Tap position indicator
x. Operation counter
xi. Break or clutch to permit only one tap change at a time
xii. Auxiliaries such as terminal blocks, space heaters, interior lighting, etc.

f) Voltage sensing and regulating device for automatic control including a time delay relay for delaying the indication of tap changing shall be provided. Settings shall be adjustable at site.

g) A remote control panel shall be provided in the electrical room and shall include, but not be limited to following:

i. Voltage regulator (solid state)
ii. Control switches for raise / lower
iii. Auto / manual selector switch
iv. Tap position indicator
v. Facia alarm annunciator with 'Acknowledge', 'Sound Cancel', 'Reset' and 'Lamp test' push buttons
vi. Audio signal for 'Tap Change in progress''
vii. Winding temperature indicator
viii. Indicating lamps for upper and lower limit of taps and for 'Tap Change in Progress'
ix. Auxiliary relays as required for remote annunciation, control
x. Auxiliaries such as terminals, fuses, space heaters, interior lighting, etc.

8.8.9.2 *Off-circuit tap changer*

Off circuit tap changer shall be provided for auxiliary transformers. It shall comprise:

a) Operating handle or wheel accessible from ground level

b) Tap position indicator

c) Padlocking arrangement with padlock.

8.8.10 Marshalling Box

The marshalling box shall be tank mounted, weather proof, vermin proof, dust proof, sheet steel (2 mm thick), enclosed and with hinged door having padlock. Door and gland plate shall be fitted with neoprene gaskets. Bottom shall be at least 600 mm from grade level. Top surface shall be sloped. The degree of protection shall be IP65.

Contacts / terminals of electrical devices / relays, etc. mounted on the transformer shall be wired to the marshalling box. Interconnecting wires between the marshalling box and the accessories / devices shall be either PVC insulated wires in GI conduits or PVC insulated, armoured cables together with provision of double compression type, brass cable glands at the marshalling box. The above mentioned cables as well as terminating the cables shall be the Contractor's responsibility.

All contacts for alarm, trip and indication circuits shall each be electrically free, designed for the auxiliary DC supply of 110 V and brought out to separate terminals in the marshalling box. Terminals shall be rated for 10 A. Disconnecting / shorting type terminal block shall be used for CT circuits.

In case of main transformers, provision for remote annunciation shall be provided with two changeover contacts for alarm condition and two changeover contacts for trip condition for each of the following conditions including but not limited to:

a) Buchholz alarm

b) Buchholz Trip

c) Oil Temperature high

d) Oil Temperature very high

e) Oil level low

f) Pressure relief device operated

g) Winding temperature high

h) Winding temperature very high

i) Conservator oil level low

8.8.11 Tests

All tests required by the specification including repeated tests and inspection that may be necessary owing to the failure to meet any tests specified, shall be carried out at the Contractor's expense. If the transformer fails to pass the tests specified, the Client shall have the option to reject the unit. Additional tests shall be conducted to locate the failure and after rectification, all tests shall be repeated to prove that the rebuilt transformer meets the specification in all respects, all at the Contractor's expense.

The tests shall be carried out in the presence of the Purchaser / Purchaser's representative. The following tests shall be carried out on the assembled transformer during inspection at the manufacturer's works.

- Measurement of resistance of windings at principal and extreme taps
- Ratio at each tap, polarity and phase relationships
- Measurement of impedance voltage at principal and extreme taps
- Measurement of no load current and no load losses at rated frequency and at both the rated voltage and 110 % rated voltage
- Measurement of efficiency at ½, ¾ and full load
- Measurement of insulation resistance
- Induced over voltage withstand test
- Separate source voltage withstand test
- Magnetic unbalance test
- Pressure Test for the tank

8.8.12 **Impulse Test and Heat Run Test**

In addition to the above tests, a withstand test with lightning impulse, chopped on the tail, shall be carried out on one limb of HV winding of the transformer if impulse test has not been already carried out on transformer of similar capacity in the last three years. Similarly heat run test shall also be carried out if the same has not been already carried out on transformer of similar capacity in the last three years. Type test certificate shall be submitted along with the bid, if such a test has been already carried out. If the type test has to be carried out, it shall be at the contractor's expense.

8.8.13 **Rejection**

The Client or Client's Representative reserves the right to reject the transformer if the same does not meet the specification requirement, subject to tolerances as per IS 2026. The rejected transformers shall be replaced by transformers complying with the requirements of this specification at the Contractor's cost.

If the commissioning of the project is likely to be delayed by the rejection of a transformer, the Client's Representative reserves the right to accept the rejected transformer until the replacement transformer is made available. Transporting the rejected and replacement transformers as well as installation and commissioning of both the transformers shall be at the Contractor's cost.

8.9 33 & 3.3 KV Switchgear

8.9.1 **Constructional Features**

Switchgear design shall comprise metal enclosed, fully compartmental execution having separate sections for each circuit. Compartments with doors for access to operating mechanism shall be so arranged as not to expose high voltage circuits. Switchgear cubicle shall be provided with hinged door on the front with facility for locking door handle. Switchboard shall be dust and vermin-proof and shall have a degree of protection of enclosure of IP 4X. All removable covers shall be gasketted all around with neoprene or superior gaskets.

Instruments, relays and control devices shall be flush-mounted on hinged door of the metering compartment located in the front portion of cubicle. The metering compartment shall be properly shielded to prevent mal-operation of electronic equipment such as numerical / static relays due to electro-magnetic fields. Separate signal earth shall be provided for such devices, if necessary.

Each switchgear cubicle shall be fitted with a label on the front and rear of the cubicle. Each switchboard shall also be fitted with label indicating the switchboard designation, rating and duty. Each relay, instrument, switch, fuse and other devices shall be provided with separate label.

Sheet steel used for fabrication of switchgear, control cabinets, marshalling boxes, etc shall be cold rolled. All panels, cabinets, kiosks and boards shall comprise rigid welded structural frames made of structural steel sections or of pressed and formed cold rolled sheet steel of thickness not less than 2.5 mm. The frames shall be enclosed by sheet steel of at least 2 mm thickness. Stiffeners shall be provided wherever necessary. All doors, removable covers, gland plates, etc. shall be of at least 2 mm thickness and shall be gasketted all round the perimeter. All doors shall be supported by strong hinges of the disappearing or internal type and braced in such a manner as to ensure freedom from sagging, bending and general distortion of panel or hinged parts. All floor mounted panels / boards shall be provided with a channel base frame. It shall be possible to extend the switchboard on both sides.

The fully draw-out modules shall have all the circuit components mounted on withdraw able type steel chassis. All power and control connections shall be of the draw out type. It shall be possible to withdraw the chassis mounted circuit components without disconnecting any connections. All draw-out contacts shall be of silver plated copper.

In case of circuit breaker compartments, suitable barriers shall be provided between breaker and all control, protective and indication circuit equipment including instrument transformers such that no live parts are accessible. External cable connections shall be through separate cable compartments for power and control cables.

One metal sheet shall be provided between two adjacent vertical sections running to the full height of the switchboard except for the horizontal busbar compartment. However, each shipping section shall have metal sheets at both ends. After isolation of the power and control connections of a circuit, it shall be possible to carry out maintenance in a compartment safely, with the bus bars and adjacent circuits alive.

8.9.2 **Circuit Breaker**

Circuit breakers shall be vacuum type. Circuit breaker along with its operating mechanism shall be mounted on a wheeled carriage moving on guides, designed to align correctly and allow easy movement. Plugs and sockets for power circuits shall be silver faced and shall be insulated with suitable insulating material shrouds. All corresponding components of circuit breaker cubicles of same rating shall be interchangeable with one another.

There shall be 'Service', 'Test' 'Fully withdrawn' positions for the breakers. In the 'Test' position the circuit breaker shall be capable of being tested for operation without energizing the power circuits, i.e. the control circuits shall remain undisturbed while the power contacts shall remain disconnected. Separate limit switches, each having a minimum of 2 'NO' + 2 'NC' contacts, shall be provided for both 'Service' and 'Test' positions of the circuit breakers.

Electrical tripping shall be performed by shunt trip coils. "Local / Remote" selector switch lockable in "Local" position shall be provided on the cubicle door. 'Red' and 'Green' indicating lamps shall be provided on cubicle door to indicate breaker close and open positions. Breaker "Service" and "Test" positions shall be indicated by separate indicating lamps on the cubicle door, along with mechanical indication of "Service" and "Test" positions on the cubicle door.

Connection of the control / interlocking circuits between the fixed portion of the cubicle and the breaker carriage shall be preferably by means of plug socket arrangement.

8.9.3 **Operating Mechanism Control**

Circuit breakers shall be operated by a motor spring charging type of mechanism. The mechanism shall be complete with motor, opening spring, closing spring and all accessories to make the mechanism a complete operating unit. Operating mechanism shall normally be operated from the breaker cubicle itself.

The tripping spring shall be charged by the closing action, to enable quick tripping. Closing of the circuit breaker shall automatically initiate recharging of the springs to enable the mechanism to be ready for the next closing stroke. Charging time for the springs shall not exceed 30 seconds. It shall be possible to manually charge the springs in an emergency. Transfer from motor to manual charging shall automatically disconnect the charging motor. All operating mechanisms shall be provided with "ON" - "OFF" mechanical indication. The charging mechanism shall be provided with mechanical indicators to show "charged" and "discharged" conditions of the spring. Failure of any spring, vibration or mechanical shock shall not cause tripping or closing of the circuit breaker.

Only one closing operation of the circuit breaker shall result from each closing impulse (manual or electrical), even if the breaker trips while the control device (manual or electrical) is being held in the "close" position.

The circuit breaker mechanism shall make one complete closing operation, once the push button (PB) or control switch has been operated and the first device in the control scheme has responded, even though the PB or control switch is released before the closing operation is complete, subject to the condition that there is no counter- impulse for tripping.

Means shall be provided to manually open and close the breakers slowly, when the operating power is not available, for maintenance and adjustments. A local manual trip device shall also be provided on the operating mechanism.

Circuit breaker control shall be on 110 V DC. Closing coils and other auxiliary devices shall operate satisfactorily at all voltages between 85-110 % of the control voltage. Trip coils shall operate satisfactorily between 70 -110 % the rated control voltage.

8.9.4 Vacuum Contactors

3.3 kV system comprises motor for driving pumps. The vacuum contactor shall be suitable for direct-on-line starting with maximum starting current of about 6 times the full load current. Vacuum contactors backed by suitable HRC fuses shall be used for controlling motor circuits.

Vacuum contactors shall have three (3) vacuum interrupters, one for each pole. The arcing period shall not exceed one half of a cycle. Current shall be chopped at very low values such that the resulting induced voltage shall be within IEC recommendations. Surge suppressor for chopping shall be incorporated in the design, if required.

A wear gauge shall be provided to check wearing of contacts at every half million operations.

Vacuum contactor coil and control supply shall be suitable for 110V DC supply and shall be designed to operate over a range of 85% to 110% voltage. Auxiliary contacts rated for 10A continuous shall be provided with each contactor to affect specified interlocks / indications etc. Spare contacts shall be available. NC contacts should open first and NO contacts should close later i.e., break before make feature shall be adopted. Fuses shall be provided for short circuit protection.

Vacuum contactors shall be interlocked with associated earthing switch such that when vacuum contactor is in 'ON' position, earthing switch cannot be made 'ON' and vacuum contactor cannot be closed unless earthing switch is in 'OFF' position.

Contactor panel shall have a three position switch (local / remote / off) and start / stop push button for motors, the latter being in local circuit.

The motor feeder contactor shall be automatically tripped under the following conditions:

a) Operation of any of the protective relays of the motor

b) Bus under voltage

c) Motor winding / bearing temperature too high

d) Starter fault

e) Any other protection / event as required by the system

8.9.5 Safety Interlocks and Features

Withdrawal or engagement of a circuit breaker shall not be possible unless it is in the open position.

Operation of a circuit breaker shall not be possible unless it is in service position, withdrawn to test position or fully drawn out. It shall not be possible to close the circuit breaker electrically in the service position, without completing the auxiliary circuit between the fixed and moving portions.

Circuit breaker cubicles shall be provided with safety shutters operated automatically by the movement of the circuit breaker carriage to cover the stationary isolated contacts when the breaker is withdrawn. Padlocking facilities shall be provided for locking the shutters positively in the closed position. It shall, however, be possible to open the shutters intentionally against spring pressure for testing purposes.

The circuit breaker carriage shall be earthed before the breaker reaches the test position from fully withdrawn position. In case of breakers with automatic disconnecting type of auxiliary disconnects, the carriage shall be earthed before the auxiliary disconnects are made and the carriage earthing shall break only after the auxiliary disconnects break.

Caution nameplate, "Caution Live Terminals" shall be provided at all points where the terminals are likely to remain live and isolation is possible only at remote end, i.e. incomer to the switchboard. Suitable interlock shall be wired for the purpose.

8.9.6 **Earthing**

Copper earthing bus shall be provided and extended throughout the length of the switchboard. It shall be bolted to the framework of each unit and brazed to each breaker earthing contact bar. It shall be located at the bottom of the board. The earth bus shall have sufficient cross section to carry the momentary short circuit and short time fault current for at least 1 second or higher without exceeding maximum allowable temperature rise. The earth bus shall be properly supported to withstand stresses induced by the momentary short circuit current.

Suitable clamp type terminals at each end of the earth bus shall be provided to suit the size of the earthing conductors. Bolted joints, slices, tap, etc. to the earth bus shall be made with at least two bolts. Positive earthing of circuit breaker frame shall be maintained when it is in the connected position and in all other positions whilst the auxiliary circuits are not totally disconnected.

Hinged doors shall be earthed through flexible earthing braid of adequate cross section. All non-current carrying metal work of the switchboard shall be effectively bonded to the earth bus.

Positive connection of the frames of all the equipment mounted in the switchboard to the earth busbar shall be maintained through insulated conductors of size equal to the earth busbar or the load current carrying conductor, whichever is smaller.

All instrument and relay cases shall be connected to earth busbar by means of 1100V grade, green coloured, PVC insulated, stranded, tinned copper, 2.5 sq. mm conductor looped through each of the earth terminals.

8.9.7 **Circuit / Busbar Earthing Facility**

It shall be possible to connect each circuit or set of 3 phase bus bars of the switchboard to earth through earthing switches. Earthing switches / earthing devices shall be mechanically interlocked with the associated breakers to prevent accidental earthing of live circuit or bus bars. In case the earthing facility comprises earthing trucks to be inserted in place of circuit breakers, separate earthing trucks shall be supplied for each type / size of breaker. The earthing facilities proposed to be provided by the Bidder shall be clearly detailed in the Bid and shall be subject to Employer's approval. Auxiliary contacts (min. 2 NO + 2 NC) shall be provided on each earth switch / earthing device and shall be wired to the terminal block for interlocking purpose.

8.9.8 Annunciators

Annunciator shall be of facia type with translucent plastic window for each alarm point. Annunciator facia plates shall be engraved in block lettering with respective alarm inscriptions. The inscriptions shall be clearly readable and visible when the respective facia light is lighted. Each annunciation window shall be provided with two lamps to provide redundancy against lamp failure. Lamps shall be replaceable from the front. Lamps shall be of clustered LED type.

All facia annunciator points shall be suitable to accept external contacts of either 'NO' or 'NC' self or hand reset type for initiating the annunciation sequence. Annunciators shall be suitable for accepting fleeting faults of duration as less as 15 milliseconds.

For static annunciator schemes, special precaution shall be taken by the Contractor to ensure that spurious alarm conditions do not appear due to influence of external magnetic fields on the annunciator wiring and switching disturbances from the neighbouring circuits within the panels/desks.

A "Lamp Test" push button shall be provided for each individual panel's group of annunciators to limit the sudden drain on the battery. Provision of testing facilities for flasher and audible alarm circuits of annunciators is to be made available. The Contractor shall give the details of the offered scheme.

Annunciators shall have following features:

- Suitable for annunciating subsequent faults immediately after the sound cancel of the previous fault.
- During lamp test, if a fault occurs, the corresponding lamp circuit shall be automatically disconnected from the "lamp test" circuit and shall start flashing.
- Designed to prevent mal-operation of the scheme or sequence when the push buttons are pressed incorrectly or in the wrong order.

"Alarm Supply Failure" Alarm scheme similar to the normal annunciation sequence, but shall operate on a different DC supply or on AC auxiliary supply.

8.9.9 Instruments

All electrical instruments and meters shall comply with IEC 60051, 61010 and IS 722, 1248. All indicating and recording instruments shall be flush mounted in dust proof cases complying with

IEC 60068 and dimensions to IEC 61554.

8.9.10 Indicating Instruments

Electrical indicating instruments shall be 144mm x 144mm square with 2400 scale. Taut band type of instruments is preferred. Taut band moving coil instruments for use on AC systems shall incorporate built-in transducers.

Instrument dials shall be white with black numbers and lettering. A red line shall be drawn on each scale to represent rated conditions.

Normal maximum meter reading shall be of the order of 60 % normal full scale deflection. Ammeters for motor feeders shall have suppressed scale to show current from full load up to six times the full load current.

Instruments shall have accuracy class of 1.0 or better. The design of the scales shall be such that it can read to a resolution corresponding to 50% of the accuracy class index.

Ammeters and current coils of Watt meters and Voltmeters shall continuously withstand 120% of rated current and 10 times the rated current for 0.5 sec., without loss of accuracy. Voltmeters and potential coils of Watt meters and VAR meters shall withstand 120% of rated voltage continuously and twice the rated voltage for 0.5 sec. without loss of accuracy.

Alternatively, instruments can be electronic / digital type with LCD display. These instruments should have high performance ratio and can be equipped with digital output (for alarms) or with interfacing facilities for communication and remote reading of parameters.

8.9.11 Metering Instruments

Watt-hour meters shall be of the induction type and shall be provided with reverse running stops.

Watt-hour and VAR hour meters shall be of the three phase two element type of accuracy class 1.0, suitable for measurement of unbalanced loads in three phase three wire circuits.

Watt-hour and VAR hour meters shall be suitable for operation from the secondary of CTs and VTs. They shall be provided with a separate 3 phase 4 wire type test blocks for the testing of the meters without disturbing the CT and VT secondary connections.

Alternatively, instruments can be electronic / digital type with LCD display. These instruments should have high performance ratio and can be equipped with digital output (for alarms).

8.9.12 Control and Selector Switches

Control and instrument switches shall be rotary type, provided with escutcheon plates clearly marked to show operating position and suitable for semi-flush mounting with only the switch front plate and operating handle projecting out. The connections shall be from the back. The contact assembly at the back of the switch shall be enclosed in dust tight removable covers.

The control switches shall be 3 position, spring return to neutral type. They shall be provided with contacts to close in 'normal after close' and 'normal after trip' position. Each switch shall have external red and green indicating lamps, (except when discrepancy type switches are called for). In addition, a semaphore indicator shall be provided for earthing switch.

Contacts of the switches shall be spring assisted and contact faces shall be of silver / silver alloy. Springs shall not be used as current carrying parts. Contact rating and configurations of the switches shall be adequate for the functions desired.

Instrument selector switches shall be of the maintained (stay-put) type. Ammeter selector switches shall have make-before-break type contacts so as to prevent open circuiting of CT secondary when changing the position of the switch.

Lockable type switches, which can be locked in a particular position, shall be provided, if required. Emergency stop buttons, if any, shall incorporate 'stay-put' features with independent reset facilities.

8.9.13 **Indicating Lamps / Pilot Lamps**

Indicating lamp shall be of the double contact, bayonet cap type rated for operation at either 230 V AC or at the specified DC system voltage as applicable. Lamps shall be provided with translucent lamp covers.

Clustered LED type lamps shall be provided. Lenses shall be glass or plastic in standard colours, red, green, blue, white and amber, in accordance with IEC 60073. Bulbs and lenses shall be interchangeable and easily replaceable from the front of the panel. Tools, if any, which are required for replacing the bulbs and lenses, shall also be included in the scope of supply.

Miniature pilot lamps may be provided with plastic marking plate contained inside square (or rectangular) front lens to provide indication of legend or symbols engraved on the marking plate.

The basis of colours shall be as follows:

Red : No Flow of Energy

Green : Flow of Energy

White : Supervision of power available, relay coil healthy, etc

Amber : Disagreement with original condition, 'abnormal' condition or 'sequence–on' condition

8.9.14 **Push Buttons**

Push buttons shall be of momentary contact type with rear terminal connections. The colour of the push button actuator shall be red for 'OPEN / STOP' and green for 'CLOSE / START'. The push button knob shall be suitably shrouded to prevent inadvertent operation. The push buttons shall be provided with integral inscription plates engraved with their designation.

All push buttons shall have independent, potential free, 2NO + 2NC contacts. The contact faces shall be of silver / silver alloy. The contacts shall be rated 10A and capable of breaking inductive load of 5A at 110V DC.

8.9.15 Space Heaters

Adequately rated anti-condensation space heaters shall be provided for each switchboard / cubicle. Space heater shall be of the industrial strip continuous duty type, rated for operation on a 230 V, 1 phase, 50 Hz, AC system. Space heater shall be provided with a single pole MCB with overload and short circuit release, a neutral link and a thermostat to cut off the heaters at 35 degree

8.9.16 Cubicle Lighting / Receptacle

Each cubicle shall be provided with interior lighting by means of 18 W fluorescent tube lighting fixture. An MCB shall be provided for the lighting circuit. The lighting fixture shall be suitable for operation from a 230 V, 1 ph, 50 Hz, AC supply. A 230 V, 1 phase, AC receptacle (socket) plug point shall be provided in the interior of each panel with an MCB.

8.9.17 Power and Control Cable Termination

Terminals for power connections shall be complete with adequate phase segregating insulating barriers, shrouds and suitable crimping type of lugs for terminating the cables.

Double compression type glands with armour and bonding clamps for the termination of all solid dielectric multicore cables shall be provided. They shall be designed to secure the armour wires to provide electrical continuity between the armour and the threaded fixing component of the gland and to provide watertight seals between the cable outer sheath and gland and between the inner sheath and threaded fixing component. The gland shall preferably project above the gland plate to avoid entry of moisture.

Earthing connectors between cable armour and earth shall be routed outside the cable gland in an approved manner. Gland insulation shall be capable of withstanding test for appropriate high voltage for one minute.

Cable terminations for HV / MV cables shall be heat / cold shrinkable type. Adequately sized shrouds / bolts shall be provided at connections to completely cover the terminations.

Where core-balance type current transformers are provided on the feeder cables for earth fault protection, glands for cables shall be insulated from earth in an approved manner.

8.9.18 Wiring For Control and Protective Circuits

All low voltage wiring for control, protection and indication circuits shall be carried out with 1100 V grade, PVC insulated cable with stranded, tinned copper conductor of minimum 1.5 sq. mm size. The size of conductor for CT circuits shall be minimum 2.5 sq. mm.

All wiring shall be run on the sides of panels and shall be neatly bunched and cleated without affecting access to equipment mounted in the panel. The wiring shall be bound and supported by clamping, roughing or lacing. Spiral wrapping will not be accepted. Wireways shall not be more than 50% full. Adequate slack wire shall be provided to allow for one restriping and reconnection at the end of each wire. When screened cables or wires are necessary, an insulating sheath shall be included. Wiring and supports shall be of fire resistant material.

Wiring shall only be jointed or teed at terminals. Terminals of the clamp type shall not have more than two wires connected.

8.9.19 **Termination and Ferrules**

Engraved core identification ferrules, marked to correspond with the wiring diagram, shall be fitted to each wire and each core of multicore cables terminated on the panels.

Moisture and oil resisting insulating material shall be used. The ferrules shall be of the interlocking type and shall grip the insulation firmly without falling off when the wire is removed.

All wires forming part of a tripping circuit shall be distinctively marked. Spare auxiliary contacts of electrical equipment shall be wired to terminal blocks.

8.9.20 **Control Wiring Terminal Blocks**

Terminal blocks shall be of 1000 V grade and stud type. Brass stud of at least 6 mm dia. with fine threads shall be used and securely locked within the mounting base to prevent turning. Each terminal shall comprise two threaded studs, with a link between them, washers, and matching nuts and locknuts for each stud. Connections to the terminals shall be at the front.

Terminals shall be numbered for identification, grouped according to function. Engraved 'black on-white' labels shall be provided on the terminal blocks describing the function of the circuit.

Terminals for circuits with voltage exceeding 110 V shall be shrouded. Terminal blocks at different voltages shall be segregated into groups and distinctively labelled. Terminals used for connecting current transformer secondary leads shall be 'disconnecting and shorting' type with a facility for earthing the secondary.

Terminal blocks shall be arranged with 100 mm clearance, between any two sets. Separate terminal stems shall be provided for internal and external wiring respectively. All wiring shall be terminated on terminal blocks, using crimping type lugs or claw type of terminations.

8.9.21 **Bus Bars**

The Bus bars shall be of Copper type and shall be provided with minimum clearances as per relevant IS. All bus bars and bus taps shall be insulated with close fitting sleeve of hard, smooth, dust and dirt free, heat shrunk PVC insulation of high dielectric strength, to provide a permanent non-ageing and non-tracking protection, impervious to water, tropical conditions and fungi. The insulation shall be non-inflammable and self-extinguishing type and in fast colours to indicate phases. The dielectric strength and properties shall hold good for the temperature range of 0 to

95 degree centigrade. If the insulating sleeve is not coloured, bus bars shall be colour coded with coloured PVC tape at suitable intervals. Busbar joints shall be of the bolted type. Spring washers shall be provided to ensure good contact at the joints. Busbars shall be thoroughly cleaned at the joints and suitable contact grease shall be applied just before making a joint.

Direct access to, or accidental contact with busbars and primary connections shall not be possible. All apertures and slots shall be protected by baffles to prevent accidental shorting of busbars due to insertion of maintenance tools.

Sequence of red, yellow and blue phases and neutral for four-pole equipment shall be left to right and top to bottom, for horizontal and vertical layouts respectively.

8.9.22 **Current Transformers**

Current transformers shall be of cast resin, bar-primary type unless specified otherwise and shall have polarity markings indelibly marked on each transformer and at the lead terminations at the associated terminal block.

Current transformers shall be able to withstand the thermal and mechanical stresses resulting from the maximum short circuit and momentary duties of the switchgear. For wound-primary type CTs, the short time current rating shall not be less than 0.5 sec.

CT core laminations shall be of high grade silicon steel.

Where multi-ratio current transformers are specified, a label shall be provided, clearly indicating the connections required for the alternative ratios. These connections shall also be shown on panel wiring diagrams.

Identification labels shall be fitted giving type, ratio, rating, output and serial numbers and duplicate rating labels are to be fitted on the exterior of the mounting chambers suitably located to enable reading without the removal of any cover or metal sheeting forming part of the structure of the switchboard.

Magnetisation characteristics, calculated performance and protective settings shall be provided by the Contractor.

8.9.23 **Relays**

All relays shall be of numerical type.

Over-current and earth fault protection relays shall be provided with instantaneous, inverse or very inverse definite minimum time, directional or non-directional characteristics as suitable.

DC trip relays shall be electrically reset type suitable for operating with the voltage reduced to 50% of normal.

All relays shall be provided with positive action indicators visible from the front.

Auxiliary relays shall be rated to operate satisfactorily between 80 and 110% of the rated voltage. Tripping relays shall be rated to operate satisfactorily between 50% and 110% of the rated voltage.

All relays shall be accessible for setting and resetting from the front. Access to setting devices shall be possible only after the front covers of the relays are removed. Resetting facilities shall however be accessible external to the relay case.

All protective relays except auxiliary relays shall be of the draw-out type. Where it is not possible to provide protective relays of the draw-out pattern, fixed type relays with facilities for plugging in a portable test plug shall be provided. Necessary test plugs shall be furnished along with the relays.

The relay shall have continuous automatic self monitoring and alarming facilities. The above feature shall not affect the relay availability.

8.9.24 **Applicable Standards**

The Switchgear shall comply with the following Standards, including those referred to therein: IEC 60044, 60186, 60255, 60265, 60282, 60298, 60466, 60529, 60694, 60787, 62271 IEC/TR2 61233 and IS 9046, 9920, 9921, 13118, 3427, 4237, 2156, 2705, 3156, 10118, 722, and 13118.

8.9.25 **Component Identification**

A component reference number shall be marked adjacent to each component. Where this is impossible, components shall be identifiable from the layout drawings provided.

The following shall be marked in all instances:

> Fuses: The rating and the circuit identification of each fuse shall be marked adjacent to the fuse base. Control, Protection and Indication Devices: The function of each control, protection and indication device shall be marked. The caption and its arrangement shall be subject to the approval of the Engineer.
>
> Preset Controls: The circuit reference and if possible, the function shall be marked adjacent to each preset control in a position where it will be clearly visible while the adjustment is being made.
>
> Connectors: The diagram reference number shall be marked on or adjacent to each connector.

Test points shall be individually marked with the diagram reference number.

The polarity of any polarized devices (e.g. diodes) shall be marked.

8.9.26 **Technical Particulars**

<u>HV switchboard</u>

Description	Unit	Particulars
General		
Type		Metal enclosed, compartmentalized, draw-out type
Rated voltage, no. of phases and rated frequency	kV / - / Hz	36 kV, 3 Phase, 50Hz
System neutral earthing		Effectively Earthed
Rated Insulation Levels		
- Rated short duration power frequency withstand voltage	kV (rms)	70
- Rated lightning impulse withstand voltage	kV (peak)	170
Rated normal current of bus bars under design ambient temperature of 50^0C and material of bulbar	A / -	(*), Copper - suitable for 100% load including future loads
Rated short-time withstand current and time	kA (rms) / sec	16 kA for 1 sec
Dynamic rating	kA (peak)	40
Constructional Requirements		
Minimum thickness of sheet steel in mm Cold rolled (Frame/Enclosure/Covers)	mm	Frame – 2.5 Doors/Covers – 2.0
Degree of protection of enclosure		IP-4X
Color finish shade		
- Interior		Glossy White
- Exterior		Light Grey Semi Glossy
Cable connection		Bottom entry and exit
Circuit Breakers		
Type		Vacuum/ SF6
Rated current inside the cubicle under design ambient temperature at 50°C	A	(*) –
Rated operating sequence		O–3 Min–CO-3 Min-CO
Rated short time breaking current	kA (rms)	16
Rated short time making current	kA (peak)	40
Rated short-time withstand current	kA (rms) /	16 kA for 1 sec

Description	Unit	Particulars
and time	sec	
Rated peak withstand current	kA (peak)	40
Min. no. of auxiliary contacts		6 NO + 6 NC after internal use by manufacturer
Type of operating mechanism		
- Normal		Spring charging for closing and tripping
- Emergency		Manual and Spring charged for closing and tripping
Auxiliary control voltage		
- Closing coil / Tripping coil	V	110V DC
- Spring charging motor	V	110V DC
- Space heater and lighting	V	230V AC
Earthing switch		Required
Current and Voltage Transformers		
Details of ratio, taps, burden, accuracy		(*)
Protective Relays		
Type		Numerical (Microprocessor based)
Auxiliary supply	V	110V DC
Details of protective relays		(*)
Switch-Disconnector		
Rated current under design ambient temperature of 50°C	A	(*)
Rated making current	kA (peak)	40
Rated peak withstand capacity	kA (peak)	40
Rated short-time withstand current and time	kA (rms) / sec	16 kA for 1 sec
Insulation levels		
Rated lightning impulse withstand voltage		
- Across the isolating distance	kV (peak)	70
- Phase to phase, between phases and across open switching devices	kV (peak)	60
Rated short duration power frequency withstand voltage		

Description	Unit	Particulars
- Across the isolating distance	kV(rms)	23
- Phase to phase, between phases and across open switching devices	kV(rms)	20
Operating mechanism		
- Closing and opening		Spring charged
- Control voltage	V	110V DC
Earthing switch		Required
HV Fuses		
Application		Indoor
Type		HRC
Rated current	A	(*)
Rated voltage	kV	36
Rated breaking capacity	kA (rms)	16

(*) Value to be ascertained by the Contractor after submitting design calculations subject to approval.

MV switchboard

Description	Unit	Particulars
General		
Type		Metal enclosed, compartmentalized, draw-out type
Rated voltage, no. of phases and rated frequency	kV / - / Hz	3.6 kV, 3 Phase, 50Hz
System neutral earthing		Earthed through resistance to limit the earth fault current to 1000 A.
Rated Insulation Levels		
- Rated short duration power frequency withstand voltage	kV (rms)	10
- Rated lightning impulse withstand voltage	kV (peak)	40
Rated normal current of bus bars under design ambient temperature of 50°C and material of bulbar	A / -	(*), Copper
Rated short-time withstand current and time	kA (rms) / sec	40 kA for 1 sec
Dynamic rating	kA (peak)	100

Description	Unit	Particulars
Constructional Requirements		
Minimum thickness of sheet steel in mm Cold rolled (Frame/Enclosure/Covers)	mm	Frame – 2.5 Doors/Covers – 2.0
Degree of protection of enclosure		IP-4X
Color finish shade		
- Interior		Glossy White
- Exterior		Light Grey Semi Glossy
Cable connection		Bottom entry and exit
Circuit Breakers		
Type		Vacuum
Rated current inside the cubicle under design ambient temperature at 50°C	A	(*)
Rated operating sequence		O–3 Min–CO-3 Min-CO
Rated short time breaking current	kA (rms)	16
Rated short time making current	kA (peak)	40
Rated short-time withstand current and time	kA (rms) / sec	40 kA for 1 sec
Rated peak withstand current	kA (peak)	100
Min. no. of auxiliary contacts		6 NO + 6 NC after internal use by manufacturer
Type of operating mechanism		
- Normal		Spring charging for closing and tripping
- Emergency		Manual and Spring charged for closing and tripping
Auxiliary control voltage		
- Closing coil / Tripping coil	V	110V DC
- Spring charging motor	V	110V DC
- Space heater and lighting	V	230V AC
Earthing switch		Required
Current and Voltage Transformers		
Details of ratio, taps, burden, accuracy		(*)

Description	Unit	Particulars
Protective Relays		
Type		Numerical (Microprocessor based)
Auxiliary supply	V	110V DC
Details of protective relays		(*)
Switch-Disconnector		
Rated current under design ambient temperature of 50°C	A	(*)
Rated making current	kA (peak)	100
Rated peak withstand capacity	kA (peak)	100
Rated short-time withstand current and time	kA (rms) / sec	40 kA for 1 sec
Insulation levels		
Rated lightning impulse withstand voltage		
- Across the isolating distance	kV (peak)	70
- Phase to phase, between phases and across open switching devices	kV (peak)	60
Rated short duration power frequency withstand voltage		
- Across the isolating distance	kV(rms)	23
- Phase to phase, between phases and across open switching devices	kV(rms)	20
Operating mechanism		
- Closing and opening		Spring charged
- Control voltage	V	110V DC
Earthing switch		Required
MV Fuses		
Application		Indoor
Type		HRC
Rated current	A	(*)
Rated voltage	kV	3.6
Rated breaking capacity	kA (rms)	16
Motor Contactors		
Type		Vacuum

Description	Unit	Particulars
Rated current	A	(*)
Rated voltage of coil	V	230 V AC, 1 phase, drawn from 3.3/0.433 kV transformer (*) on each bus section

8.9.27 Test Terminal Blocks

Test terminal blocks, if any, shall be provided for secondary injection and testing of relays. A suitable metering block shall be provided for the connection of a portable precision instrument to be operated when required for specific plant testing purposes.

8.9.28 Tests

The following routine tests shall be carried out on the assembled switchboard / panel during inspection at the manufacturer's works in addition to other tests as per applicable standards.

- Primary injection tests to ensure correct ratios and polarity of current and voltage transformers and of the current operated protection relays and direct acting coils, over their full range of settings.
- Balance earth fault stability test by primary current injection. Care must be taken to reproduce accurately the burdens of interconnecting cables. A further test to ensure correct polarity must be made after assembly.
- Tests on auxiliary relays at normal operating voltages by operation of associated remote relays.
- Correct operation of sequencing and control circuits at normal operating voltages by operation of local control switches, and simulation of operation from remote control positions.
- Carry out functionality tests, check interfacing status contacts and instrumentation.
- Checking of Differential protection relay.
- One minute power-frequency voltage dry withstand tests on the main circuits
- One minute power-frequency voltage dry withstand tests on auxiliary circuits
- Insulation resistance tests
- All circuit breakers shall be subject to the following tests:
- Routine tests including HV pressure test, milli-volt drop tests and mechanical tests.
- To ensure the operation of the dc closing coil and satisfactory closing of the circuit breaker with the voltage of the coil down to 80% of its rated voltage, and that mal-operation does not occur with a voltage on the coil of 120% of its rated voltage.
- Inter changeability of withdraw-able identically equipped circuit breakers, and checking of all mechanical and electrical interlocks.
- Type test figures for heat test runs performed on identical panel types shall be made available.

8.10 L.V. Switchboards / Main Distribution Boards

The following clauses shall be deemed to apply for Main PCC, MCC, Sub-DBs/panels, marshalling boxes, control cabinets/panels, etc.

8.10.1 General Constructional Features

Sheet steel used for fabrication of switchboards, control cabinets, marshalling boxes, etc shall be cold rolled.

All panels, cabinets, kiosks and boards shall comprise rigid welded structural frames made of structural steel sections or of pressed and formed cold rolled sheet steel of thickness not less than 2 mm. The frames shall be enclosed by sheet steel of at least 2 mm thickness. Stiffeners shall be provided wherever necessary.

All doors, removable covers, gland plates, etc. shall be of at least 1.6 mm thickness and shall be gasketted all round the perimeter.

All doors shall be supported by strong hinges of the disappearing or internal type and braced in such a manner as to ensure freedom from sagging, bending and general distortion of panel or hinged parts.

All floor mounted panels/boards shall be provided with a channel base frame. Total height of all floor mounted cubicles/panels shall not be greater than 2300 mm. Where steel pedestals for mounting of boards/panels are specified, the total height including that of the pedestal shall not exceed 2300 mm.

Switchboard/control cabinet/panel shall be dust and vermin proof. Degree of protection of the enclosure shall be IP 54 for indoor installations and IP 55 for outdoor installations.

Separate, segregated metal clad compartments shall be provided for main and auxiliary bus bars, each feeder and cable alleys. Metal clad cubicles/modules shall be provided with hinged doors in the front, with facility for padlocking door handles. More than one module may be arranged in the same vertical section. . The switchboard enclosure shall conform to "Form – 4" as per IS-8623. It shall be possible to extend the switchboard on both sides.

All the module shall be of fully draw-out type. The breaker carriage shall be fitted with positive guides to ensure proper alignment. All corresponding components of circuit breaker cubicles of same rating shall be interchangeable with one another.

The fully draw-out modules shall have all the circuit components mounted on withdrawable type steel chassis. All power and control connections shall be of the draw out type. It shall be possible to withdraw the chassis mounted circuit components without disconnecting any connections. All draw-out contacts shall be of silver plated copper.

In case of circuit breaker compartments, suitable barriers shall be provided between breaker and all control, protective and indication circuit equipment including instrument transformers. External cable connections shall be through separate cable compartments for power and control cables.

Instruments, relays and control devices shall be mounted flush on hinged door of the cubicles. Switchboard shall be complete with inter-panel wiring.

Each switchboard shall also be fitted with a label indicating its title. Each cubicle shall be fitted with a label on the front and rear of the cubicle. Each relay, instrument, switch, fuse, contactor and MCCB/MCB shall be provided with a separate label.

One metal sheet shall be provided between two adjacent vertical sections running to the full height of the switchboard except for the horizontal busbar compartment. However, each shipping sections shall have metal sheets at both ends.

After isolation of the power and control connections of a circuit, it shall be possible to carry out maintenance in a compartment safely, with the busbars and adjacent circuits alive.

The current rating of outgoing feeders of any switchboard shall not be less than 10% of that of the incoming feeder. Deviation from this requirement shall be subject to the approval of the engineer.

8.10.2 **Busbars**

The Busbars shall be of Copper and shall be provided with minimum clearances as per relevant IS. All busbars and bus taps shall be insulated with close fitting sleeve of hard, smooth, dust and dirt free, heat shrunk PVC insulation of high dielectric strength, to provide a permanent non-ageing and non-tracking protection, impervious to water, tropical conditions and fungi. The insulation shall be non-inflammable and self extinguishing type and in fast colours to indicate phases. The dielectric strength and properties shall hold good for the temperature range of 0 to 95 degree centigrade. If the insulating sleeve is not coloured, bus bars shall be colour coded with coloured PVC tape at suitable intervals.

Busbar joints shall be of the bolted type. Spring washers shall be provided to ensure good contact at the joints. Busbars shall be thoroughly cleaned at the joints and suitable contact grease shall be applied just before making a joint.

Direct access to, or accidental contact with busbars and primary connections shall not be possible. All apertures and slots shall be protected by baffles to prevent accidental shorting of busbars due to insertion of maintenance tools.

Sequence of red, yellow and blue phases and neutral for four-pole equipment shall be left to right and top to bottom, for horizontal and vertical layouts respectively.

8.10.3 **Circuit Breakers**

8.10.3.1 *Air Circuit Breaker (ACB)*

Circuit breakers shall be operated by a motor spring charging type of mechanism. The motor operated spring charged mechanism shall be complete with motor, opening spring, closing spring and all accessories to make the mechanism a complete operating unit.

The tripping spring shall be charged by the closing action, to enable quick tripping. Closing of the circuit breaker shall automatically initiate recharging of the springs to enable the mechanism to be ready for the next closing stroke. Charging time for the springs shall not exceed 30 seconds. It shall be possible to manually charge the springs in an emergency. Transfer from motor to manual charging shall automatically disconnect the charging motor. The charging mechanism shall be provided with mechanical indicators to show "charged" and "discharged" conditions of the spring. Failure of any spring, vibration or mechanical shock shall not cause tripping or closing of the circuit breaker.

Only one closing operation of the circuit breaker shall result from each closing impulse (manual or electrical), even if the breaker trips while the control device (manual or electrical) is being held in the "close" position.

The circuit breaker mechanism shall make one complete closing operation, once the push button has been operated and the first device in the control scheme has responded, even though the PB is released before the closing operation is complete, subject to the condition that there is no counter- impulse for tripping.

Means shall be provided to manually open and close the breakers slowly, when the operating power is not available, for maintenance and adjustments. A local manual trip device shall be provided on the operating mechanism.

All operating mechanisms shall be provided with "ON" - "OFF" mechanical indication.

Closing coils and other auxiliary devices shall operate satisfactorily at all voltages between 85-110 % of the control voltage. Trip coils shall operate satisfactorily between 70 -110 % the rated control voltage.

The Breaker shall be provided with Microprocessor based releases for Inverse-time delayed overload releases for the phases, Short-time delayed short-circuit releases and earth-fault releases.

The breaker service Short Circuit breaking capacity (I_{CS}) shall be equal to ultimate Short Circuit capacity (I_{CU}) and shall be equal to short time withstand current of Breaker (I_{CW}).

8.10.3.2 *Moulded Case Circuit Breaker (MCCB)*

MCCBs shall be of the air break, quick make, quick break and trip free type and shall be totally enclosed in a heat resistant, moulded, insulating material housing.

MCCBs shall have an ultimate short circuit capacity not less than the prospective short circuit current at the point of installation.

MCCBs shall have a service short circuit breaking capacity (I_{CS}) equal to the ultimate short-circuit capacity (I_{CU}).

Each pole of MCCB shall be fitted with a bi-metallic thermal element for inverse time delay protection and a magnetic element for short circuit protection. Alternatively, they shall be fitted with a solid state protection system. Such a protection system shall be fully self-contained, needing no separate power supply to operate the circuit breaker tripping mechanism. Thermal element shall be adjustable. Adjustments shall be made simultaneously on all poles from a common facility. Thermal elements shall be ambient temperature compensated.

The MCCBs shall be provided with the following features.

- Common trip bar for simultaneous tripping of all poles
- Shrouded terminals
- Time for clearing short circuit current of 20 msec.
- 2 NO + 2 NC auxiliary contacts

8.10.3.3 *Miniature Circuit Breaker (MCB)*

MCB shall be hand operated, air break, quick make, quick break type.

Operating mechanisms shall be mechanically trip-free from the operating knob to prevent the contacts being held closed under overload or short-circuit conditions.

Each pole shall be fitted with a bi-metallic element for overload protection and a magnetic element for short-circuit protection. Multiple pole MCBs shall be mechanically linked such that tripping of one pole simultaneously trips all the other poles. The magnetic element tripping current classification shall be of the type suitable for the connected load. Where this is not specified, it shall be Type C. The short circuit rating shall be not less than that of the system to which they are connected.

8.10.4 **Contactors**

The power contactors used in the switchboard shall be of, air break, single throw, triple pole, electromagnetic type. Contactors shall be suitable for uninterrupted duty and rated for Class AC3 duty in accordance with the latest edition of IS 13947.

Operating coils of all contactors shall be suitable for operation on 240 V, single phase, 50 Hz supply.

Contactors shall be provided with at least two pairs of NO and NC auxiliary contacts.

Contactors shall not drop out at voltages down to 70 % of coil rated voltage.

Contactors shall be provided with a three element, positive acting, ambient temperature compensated, time lagged, hand reset type thermal overload relay with adjustable settings. The hand reset button shall be flush with the front door of the control module, and shall be suitable for resetting the overload relay with the module door closed. Relays shall be either direct connected or CT operated. Overload relay and reset button shall be independent of the "Start" and "Stop" push buttons. All contactor shall all be provided with single phasing preventer (SPP).

Motor starters shall be complete with auxiliary relays, timers and necessary indications.

8.10.5 **Switch Disconnectors and Fuses**

LV switch disconnectors shall be of the load break, fault make, group operated type. For use on 3-phase systems, the switches shall be of the triple pole type with a link for neutral wire. For use on single phase system and DC systems, the switches shall be of the two pole type.

Switch disconnectors shall be of the heavy duty, quick make and quick break type. Their contacts shall be silver plated, and contact springs shall be of stainless steel. Their handles shall have provision for locking in both fully open and fully closed positions. Mechanical ON-OFF indication shall be provided.

Switch disconnectors for controlling motor circuits shall be of the load break, fault make type, and shall be capable of breaking locked rotor current of the associated motor. Where combination units of switch disconnector and fuses are used, the following interlocks shall be incorporated.

The fuses should not be accessible unless the switch disconnector is in fully open condition.

It should not be possible to close the switch disconnector when the fuse cover is open, but an authorised person may override the interlock and operate the switch disconnector. After such an operation, the cover shall be prevented from closing if the switch disconnector is left in the "ON" position.

All fuses shall be of the HRC cartridge type, mounted on plug-in type of fuse bases. Fuses shall be provided with visible indicators to show that they have operated. Current vs. time characteristics of all types of fuses shall be furnished to the Engineer.

Fuses and links functionally associated with the same circuit shall be mounted side by side.

An adequate number of spare fuse cartridges of each rating shall be supplied and fitted in clips inside the panel.

8.10.6 **Instrument Transformers**

Current transformer (CT) shall have polarity markings indelibly marked on each transformer and at the lead terminations at the associated terminal block.

CT shall be able to withstand the thermal and mechanical stresses resulting from the maximum short circuit current.

CT core laminations shall be of high grade silicon steel.

Secondary winding of voltage transformer (VT) shall be rated for a three phase line to line voltage of 110 V. Identification labels giving type, ratio, output and serial numbers shall be provided.

8.10.7 Relays

Main protective relays shall be of Numerical type.

All relays shall be enclosed in rectangular shaped, dustproof cases and shall be suitable for flush mounting.

All relays shall be accessible from the front for setting and resetting. Access to setting devices shall be possible only after the front covers of the relays are removed. Resetting facilities shall however be accessible external to the relay case.

All protective relays shall be of the draw-out type and shall be provided with operation indicators visible from the front.

Auxiliary relays and timers shall be rated to operate satisfactorily between 70 % and 110 % of the rated voltage.

8.10.8 Control and Selector Switches

Control and selector switches shall be of the rotary type, having enclosed contacts, which are accessible by the removal of the cover. Control and selector switches for instruments shall be flush mounted on the front of the panels and desks.

All control switches shall be of the spring return to normal type and shall have momentary contacts. Selector switches shall be of the stay-put, maintained contact type.

8.10.9 Indicating Instruments & Meters

Electrical indicating instruments shall be 110 mm square with 240^0 scale. Taut band type of instruments is preferred. Taut band moving coil instruments for use on AC systems shall incorporate built-in transducers.

Instrument dials shall be white with black numbers and lettering.

Normal maximum meter reading shall be of the order of 60 % normal full scale deflection. Ammeters for motor feeders shall have suppressed scale to show current from full load up to six times the full load current.

Watt hour meters shall be of the induction type and shall be provided with reverse running stops.

Instruments shall have an accuracy of Class 1.0.

8.10.10 Indicating Lamps

Indicating lamps shall be of the cluster LED type, with low watt consumption. Indicating lamp shall be of the double contact, bayonet cap type rated for operation at either 240 V AC or at the specified DC system voltage as applicable. Lamps shall be provided with translucent lamp covers.

Bulbs and lenses shall be interchangeable and easily replaceable from the front.

8.10.11 Push Buttons

"Start" and "Stop" push buttons shall be coloured green and red respectively. Stop Push Button shall be lockable stay-put type with Mushroom head.

8.10.12 Space Heaters

Adequately rated anti-condensation space heaters shall be provided, one for each control panel, for each switchboard and for each marshalling kiosk.

Space heater shall be of the industrial strip continuous duty type, rated for operation on a 230 V, 1 phase, 50 Hz, AC system.

Each space heater shall be provided with a single pole MCB with overload and short circuit release, a neutral link and a control thermostat to cut off the heaters at 35^0 C.

8.10.13 Cubicle Lighting / Receptacle

Each control panel, control cabinet, marshalling box, etc. shall be provided with interior lighting by means of a 20 W fluorescent tube lighting fixture. A MCB shall be provided for the lighting circuit. The lighting fixture shall be suitable for operation from a 230 V, 1 ph, 50 Hz, AC supply.

A 230 V, 1 phase, AC receptacle (socket) plug point shall be provided in the interior of each panel with a MCB for connection of hand lamp.

8.10.14 Safety Arrangements

All terminals, connections and other components, which may be "live" when front access door is open, shall be adequately screened. It shall not be possible to obtain access to an adjacent cubicle or module when any door is opened. Components within the cubicles shall be labelled to facilitate testing.

8.10.15 Power and Control Cable Terminations

Equipment terminal blocks for power connections shall be complete with adequate phase segregating insulating barriers, shrouds and suitable crimping type of lugs for terminating the cables. Double compression type cable glands shall be provided for all power and control cables.

Earthing connectors between cable armour and earth shall be routed outside the cable gland in an approved manner. Gland insulation shall be capable of withstanding a high voltage test of 3000 V for one minute.

8.10.16 Wiring for Control and Protective Circuits

All wiring for control, protection and indication circuits shall be carried out with 1100 V grade, PVC insulated cable with stranded, tinned copper conductor of minimum 1.5 sq. mm size. The size of conductor for CT circuits shall be minimum 2.5 sq. mm.

All wiring shall be run on the sides of panels and shall be neatly bunched and cleated without affecting access to equipment mounted in the panel. All wiring shall be taken to terminal blocks without joints or tees in their runs.

All wiring shall be colour coded as given below.

Instrument Transformer : Red, Yellow or Blue determined by the circuit phase with which the wire is associated.

A C phase wire	White
A C neutral	Black
D C circuits	Grey
Earth connections	Green

Engraved core identification ferrules, marked to correspond with the wiring diagram, shall be fitted to each wire and each core of multicore cables terminated on the panels. Ferrules shall fit tightly on wires, without falling off when the wire is removed. Ferrules shall be of yellow colour with black lettering.

All wires forming part of a tripping circuit shall be provided with an additional red ferrule marked 'T'. Each wire shall be identified by a letter to denote its function followed by a number to denote its identity, at both ends. Unused core of multicore cables shall be ferruled U1, U2 etc., at both ends, and connected to spare terminals. Spare auxiliary contacts of electrical equipment shall be wired to terminal blocks.

8.10.17 **Control Wiring Terminal Blocks**

Terminal blocks shall be of the 1000 V grade and stud type. Brass stud of at least 6 mm dia. with fine threads shall be used and securely locked within the mounting base to prevent turning. Each terminal shall comprise two threaded studs, with a link between them, washers, and matching nuts and locknuts for each stud. Connections to the terminals shall be at the front.

Terminals shall be numbered for identification, grouped according to function. Engraved 'black on-white' labels shall be provided on the terminal blocks describing the function of the circuit.

Terminals for circuits with voltage exceeding 110 V shall be shrouded. Terminal blocks at different voltages shall be segregated into groups and distinctively labelled.

Terminals used for connecting current transformer secondary leads shall be 'disconnecting and shorting' type with a facility grounding the secondary.

Terminal blocks shall be arranged with 100 mm clearance, between any two sets.

Separate terminal stems shall be provided for internal and external wiring respectively.

All wiring shall be terminated on terminal blocks, using crimping type lugs or claw type of terminations.

8.10.18 **Test Terminal Blocks**

Test terminal blocks, if any, shall be provided for secondary injection and testing of relays. A suitable metering block shall be provided where specified for the connection of a portable precision instrument to be operated when required for specific plant testing purposes.

8.10.19 **Earthing of Switchboards / Panels**

Each switchboard, control panel, etc. shall be provided with an earth busbar running along its entire length. The earth busbar shall be located at the bottom of the board/panel.

Earth busbars shall be of copper and shall be rated to carry the rated symmetrical short circuit current of the associated board/panel for one second, unless otherwise specified. Earth busbars shall be properly supported to withstand stresses induced by the momentary short circuit current of value equal to the momentary short circuit rating of the associated switchboard/panel.

Positive connection of the frames of all the equipment mounted in the switchboard to the earth busbar shall be maintained through insulated conductors of size equal to the earth busbar or the load current carrying conductor, whichever is smaller.

All instrument and relay cases shall be connected to earth busbar by means of 1100 V grade, green coloured, PVC insulated, stranded, tinned copper, 2.5 sq. mm conductor looped through the case earth terminals.

8.10.20 **Applicable Standards**

The following standards and codes of practice shall be applicable. These shall be the latest editions including all official amendments and revisions. The standards referred to therein shall also be applicable.

Air break switches, MCCBs, etc. for voltage not exceeding 1000 V AC or 1200 V DC	IS 13947
Current transformer	IS 2705 / IEC 60044
Voltage transformer	IS 3156 / IEC 60044, 60186
Electrical Relays	IS 3231, 3842 / IEC 60255
Contactors for voltage	IS 13947 / IEC 60947
not exceeding 1000 V AC Control Switches	IS 6875 / IEC 60947
High Voltage Fuses	IS 9385 / IEC 60282
Low voltage Fuse	IS 13703 / IEC 60269
Electrical direct acting indicating instruments	IS 1248 / IEC60051

AC electricity meters of induction type for voltage greater than 1000 volts	IS 722, 8530 / IEC 60145, IEC 60211
Porcelain post insulators for system with nominal voltages greater than 1000 volts	IS 2544
Specification for copper rods and bars for electrical purposes	IS 613
Specification for low voltage switchgear and control gear	IS 13947 / IEC 60947
Degree of protection provided by enclosures for low voltage switchgear and control gear	IS 13947 / IEC 60947
Marking and arrangement for switchgear, busbars, main connections and auxiliary wiring	IS 5578 / IS 11353
Code of practice for selection, installation and maintenance of switchgear and control gear	IS 10118
Miniature Circuit Breakers	IS 8828 / IEC 60898
Control Switches/ Push buttons	IS 6875

8.10.21 **Technical Particulars**

The specific technical particulars of switchboard shall be as given below:

Sr. No.	**Description**	**Particulars**
1	Rated voltage, Phases and Frequency	433 V, 3 Ph, 50 Hz
2	Type of Construction	Single front, draw out type
3	Maximum system voltage	476 V
4	One minute Power Frequency withstand voltage	
a)	Power circuit	3000 V (rms)
b)	Control circuit	2000 V (rms)
c)	Auxiliary circuit connection to secondary of CTs	2000 V (rms)
5	Current rating of busbars over design ambient temperature of 50^{o}C	(*)
6	Short circuit withstand for main and auxiliary busbars (1 sec.)	(*)
7	Maximum temperature of main and auxiliary bus bars at continuous rated current rating under site design ambient temperature of 50 degree C	85 ^{0}C

Sr. No.	Description	Particulars
8	Colour finish shade as per IS:5	
a)	Interior	Glossy white
b)	Exterior	Light grey, semi-glossy, shade 631 of IS 5
9	Earthing bus material and size	Copper, 25 x 6 mm
10	Clearances in air of live parts	25.4 mm
11	Power contactors	
a)	Contactor rated duty	AC3
b)	Utilisation category	Uninterrupted
12	Motor Starters	For motor < 5.5 kW – DOL For motor > 5.5 kW – Star-Delta up to 75kW For motor ≥ 75 KW-Soft Starter/VFD
14	Type of Mounting	Floor
15	Cable Entry	(*)

(*) To be worked out by the contractor based on approved calculations submitted by contractor

8.10.22 **Tests**

All the routine tests as per relevant standards alongwith the following shall be carried out on the assembled switchboard/panel during inspection at the manufacturer's works in addition to other tests.

One minute power-frequency voltage dry withstand tests on the main circuits

One minute power-frequency voltage dry withstand tests on the auxiliary circuits

8.11 L.V Capacitor Bank with Automatic Power Factor Correction

8.11.1 **General**

The capacitor bank shall be complete with all accessories that are necessary or essential for efficient operation. Such accessories shall be deemed to be within the scope of supply whether specifically mentioned or not. It shall be complete with the required capacitors along with the supporting post insulators, steel rack assembly, copper bus bars, copper connecting strips, foundation channels, fuses, fuse clips, etc. The steel rack assembly shall be hot dip galvanised.

The capacitor bank may comprise of suitable number of single phase units in series parallel combination. However, the number of parallel units in each of the series racks shall be such that failure of one unit shall not create an over voltage on the units in parallel with it, which will result in the failure of the parallel units. The assembly of the banks shall be such that it provides sufficient ventilation for each unit.

Each capacitor case and the cubicle shall be earthed to a separate earth bus.

Capacitor shall conform to IS 2834. Capacitors shall be of mixed dielectric or APP type. Each unit shall satisfactorily operate at 135 % of rated kVAR including factors of overvoltage, harmonic currents and manufacturing tolerance. The units shall be capable of continuously withstanding satisfactorily any overvoltage up to a maximum of 10 % above the rated voltage, excluding transients.

Each capacitor unit/bank shall be fitted with directly connected continuously rated, low loss discharge device to discharge the capacitors to reduce the voltage to 50 volts within one minute upon disconnection, in accordance with the provisions of the latest edition of IS:2834.

8.11.2 **Unit Protection**

Each capacitor unit shall be individually protected by a HRC fuse suitably rated for load current and interrupting capacity, so that only the faulty capacitor unit will be disconnected without causing the bank to be disconnected. An operated fuse shall give visual indication so that it may be detected during periodic inspection. The fuse breaking time shall co-ordinate with the pressure built up within the unit to avoid explosion. Mounting of the individual fuse should be internal to the capacitor case.

The Automatic Power Factor Correction relay shall be of microprocessor based type and shall automatically switch ON/OFF the capacitor banks to attain the value of "pf" close to the set value. Switching shall follow first in first out (FIFO) method to ensure uniform use of all capacitor banks. At least eight steps shall be provided for switching.

8.11.3 **Capacitor (APFC) Control Panel**

Capacitor and capacitor control shall be housed in a metal enclosed cubicle. Capacitor shall be housed in the lower compartment and capacitor control unit at the top compartment, the two compartments being segregated.

The cubicle shall be fabricated out of 2 mm thick cold rolled sheet steel and shall of a degree of protection of IP 54. The panel shall l comprise:

- Isolating MCCB
- Contactors with overload element
- Relays responsive to current/voltage/kVAR/pf for automatic switching
- Sequencing devices, timers and auxiliary relays for automatic sequential switching of capacitor units in and out of circuit
- Auto-manual selector switch
- Microprocessor based Automatic Power Factor Correction (APFC) Relay

- Push button for opening and closing the power circuit
- Red and Green lamps for capacitors ON/OFF indication
- Protective relays to protect the healthy capacitor units when one unit fails in a series connection
- Space heater and cubicle lighting

8.11.4 **Technical Particulars**

The specific technical particulars of capacitors shall be as given in the table below.

Sr. No.	Description	Particulars
1	Rated Capacity	(*)
2	Rated voltage, frequency and phases	433, V 50 Hz, 3 Phase
3	Insulation level	3 kV (rms)
4	Capacitor bank connection	Delta
5	Control	Automatic by "pf" correction relay (micro-processor based)
6	No. of steps for control	(*)
7	Capacitor Bank Enclosure	
a)	Type	Floor mounted
b)	Colour finish / shade	Interior : glossy white Exterior : Light grey, semi glossy, shade 631 of IS 5

(*) To be worked out by the contractor based on approved calculations submitted by contractor

8.12 Battery, Battery Charger and D.C Distribution Board

DC equipment shall comply with IEC 60896 including those standards referred to therein.

8.12.1 **Requirements**

Following items shall be covered in the Contract:

a) One no. 110 V Nickel Cadmium type Battery Bank (Minimum capacity of Battery - 75AH) in each substation.

b) Two nos. (1W+1S) Float-cum-boost charger for 110 V battery in each substation.

c) DC distribution board.

All connections between battery, battery chargers and DC distribution board shall be designed for effective segregation between positive and negative leads.

Battery offered shall be Nickel Cadmium (Ni-Cd) type. Nickel hydroxide and Cadmium hydroxide shall be used for positive and negative electrode respectively. Aqueous solution of Potassium hydroxide with small quantities of lithium hydroxide shall be used as electrolyte. It shall be used only for ion transfer and shall not chemically change during charging/ discharging.

The containers shall be transparent and preferably be made of toughened glass or plastic and provided with acid level indicator. The battery shall be rated on 5-hour basis and for the specified ambient temperature. The battery shall have maximum recharge time of 8 hours.

Terminal posts shall be designed to accommodate external bolted connection conveniently and positively. Each terminal post shall have two bolt holes of the same diameter, preferably at right angles to each other. The bottom hole shall be used to terminate the inter-cell connection. The top hole shall be left for external terminal connections. Bolts, heads and nuts, except seal nuts, shall be hexagonal and shall be lead covered. The junction between terminal posts and cover and between cover and container shall be so sealed as to prevent any seepage of electrolyte.

Required quantity of electrolyte for first filling with 10% extra shall be supplied in non-returnable containers. Each battery shall be complete with following accessories, as applicable, that include, but are not limited to:

a) Battery racks

b) Porcelain insulators, rubber pads, etc.

c) Set of inter-cell, inter-tier and inter-bank connectors as required for the complete installation.

d) Electrolyte for first filling + 10% extra.

1 set of accessories for testing and maintenance shall also be provided suitable for all the three battery banks.

i.	One	-	-3, 0, +3 volts DC voltmeter with built-in discharging resistor and suitable leads for measuring cell voltage.
ii.	One	-	Filler hole thermometer fitted with plug and cap and having specific gravity correction scale.
iii.	Three	-	Pocket thermometers
iv	Two	-	Cell lifting straps
v	One set Each of	-	Terminals and cable boxes with glands for connecting cable as required.
			Spare connectors
			Spare vent plugs
			Spare nuts and bolts

Suitable set of spanners

Each battery shall be mounted in a manner that permits easy accessibility to any cell. The racks shall be suitable for fixing on flat concrete floor. The complete racks shall be suitable for bolting end to end.

It shall be the responsibility of the Contractor to provide batteries of adequate capacities to meet specified requirements pertaining to control, indication, annunciation, etc. and emergency lighting. For computing battery capacity, it shall be assumed that the battery is fully charged at the beginning of loading cycle and is discharged to a voltage of 1.2 volts per cell at the end of the loading cycle. The battery shall have minimal difference (approx. 0.3 V per cell) between float and boost charging voltages.

8.12.2 **Battery Charger**

The float-cum-boost type battery charger shall comprise silicon controlled rectifiers (SCRs) connected in a full wave bridge circuit. Each battery charger shall be suitable for float charging the battery under normal conditions and boost charging the battery when it has discharged during service conditions. The changeover from float to boost mode and vice versa shall be automatic.

The rectifier transformer shall be dry type and double wound with required number of taps. The DC output voltage during float charging shall be stabilized within + 1% of the set DC bus voltage for AC input voltage variation of +10%, frequency variation of + 5% and DC load variation from 0 - 100%. The voltage regulation shall be achieved by a constant voltage regulator having fast response SCR control. The ripple content shall be within 1% of DC output nominal voltage with battery disconnected and shall be designed to have voltage regulation of 1%. Also in any mode of operation, the maximum harmonics in the charger output shall not exceed 5%.The setting of the output DC bus voltage shall be adjustable between + 10% of nominal rated voltage. There shall be provision for manual control if auto mode fails. Line surge suppressers shall be provided.

For boost charging the discharged battery after a mains failure, the rectifier shall charge the battery at high rate limited to the maximum boost charging voltage. The boost charging shall come on only when selected for boost mode manually. In auto control, the DC output current shall be stabilized within +2% for AC input voltage and frequency variation of + 10% and + 5% respectively. There shall be provision for manual control if auto-mode fails. Boost charging time for charging the battery to full capacity from fully discharged condition shall not exceed 8 hours.

In the float charging mode, the charger shall be designed for supplying:

- The DC loads of control, indication and annunciation circuits that remain energized during normal operation and the momentary closing and trip coil loads of circuit breakers, vacuum contactors; and
- The float charging current of the battery.
- 25% margin over the above load

Battery charging equipment complete with all accessories shall be housed in a free standing sheet steel cubicle having degree of protection of IP 5X. Sheet steel used for construction shall be 2 mm thick. The units shall be wired using 1100 V grade, PVC insulated, stranded copper conductor cables.

Each battery charger shall be provided with accessories that include, but not limited to the following:

- Silicon controlled rectifiers connected in full wave bridge circuit with ripple control devices and transient suppression network.
- 230 V AC compact fluorescent lamp fixture for internal lighting with MCB
- Automatic voltage regulator unit with manual / auto control switch
- Coarse and fine control potentiometers for manual control
- Selector switch for mode of charging i.e. float charging / boost charging
- Off-load tap changing switch for changing the taps of the transformer
- DC voltmeter with fuses and a three position selector switch
- DC ammeter with shunt
- AC ammeter with selector switch for incoming AC power
- AC voltmeter with selector switch for incoming AC power
- MCB for incoming AC supply along with surge suppressers
- Switch-fuse / MCB on DC output side with kick fuses and alarm contacts
- Voltage dropping diodes in load circuit during boost charging mode
- DC undervoltage relay and earth fault relay
- AC / DC switching relays for alarm and indication circuits including buzzer
- Cubicle space heater suitable for 230 V AC, 1 ph, 50 Hz supply, with MCB and thermostat

Each battery charger shall be provided with the following alarms / indications:

- AC and DC supply 'ON'
- AC and DC supply fail
- Modes of charging
- Over voltage
- Under voltage on DC side
- Earth fault on DC side
- AC / DC MCB trip

The DC circuit switching shall be through DC MCBs only.

8.12.3 D.C. Distribution Board

The distribution board shall be of floor mounting design. Entry for incoming and outgoing cables shall be from the bottom. Bus bars shall be of copper. Incomers, bus coupler and outgoing circuits shall be controlled by suitably rated double pole MCBs type suitable for DC application. Contractor shall furnish proposed single line diagram of the board along with the Bid.

Constructional features, pre-treatment, painting and other aspects shall comply with the specifications for LV switchboard.

An earth busbar of 25x3 mm copper flat shall be provided along the length of the DB at the bottom. Two nos. earthing terminals shall be provided on the external face of the board for connection to the earthing grid.

8.12.4 **Tests**

The batteries, chargers and distribution boards and their components shall be subjected to routine/ acceptance tests as per the applicable standards. For battery, following tests are also to be carried out:

- Capacity test
- Test for voltage charging and discharging
- Ampere-hour and watt-hour efficiency test

Certificates of type tests carried out on similar equipment shall be furnished.

8.13 Non-Segregated Bus Duct

8.13.1 **Bus Enclosure**

The enclosure shall be made of aluminium alloy, the grade aluminium alloy shall be indicated by the BIDDER in his Bid and shall be subject to the PURCHASER'S approval.

The entire bus duct shall be designed for indoor/outdoor installation, with a dust and vermin-proof construction. Bus duct installations meant for outdoor application shall be of weather proof construction and shall have degree of protection better than or equal to IP-55. Outdoor portion of bus duct shall be provided with rain hood.

The inside of the bus enclosure shall be treated with a matt paint of dark colour, preferably black to facilitate efficient heat dissipation. The bare enclosure with above painting shall be designed so as not to exceed the temperature specified in IS: 8084.

Joints consisting of metallic expansion bellows shall be provided on the bus enclosure at following points:

- At terminations at transformers
- At terminations at switchgear cubicles
- In the run of the bus duct in case of long lengths as required.

Flexible expansion joints for the enclosure shall be provided wherever deemed necessary. The flexible joints shall take care of expansion and contraction due to temperature variations and fault conditions. Necessary bonding shall be provided at the above expansion joints if joints are made of insulating material.

Three-phase terminal enclosures shall be provided with flanged ends with drilling dimensions to suit the flange at equipment terminals. The flanges shall be provided with gaskets, nuts, bolts etc.

Provision shall be made for periodic inspection of insulators by means of inspection covers. The inspection covers shall be provided at the bottom with quick-acting stainless steel clamps and shall have gaskets. There shall be no joints or fixing bolts on the top surface through which water could seep through.

The drain plugs shall be easily removable for cleaning purposes.

The gasket material and thickness shall be so selected as to satisfy the operating conditions imposed by temperature, weathering, durability, etc. Care shall be exercised to ensure that covers fit easily, that the required compression of the gaskets can be obtained without damage to the inspection covers by bolts and that covers do not bend after this compression has been applied. Over-compression of the gaskets shall be avoided.

The material of the gasket shall preferably be neoprene closed-cell sponge rubber or equivalent.

Flange gaskets shall be provided at the equipment terminal connections.

The bus duct shall not have any through bolts. All nuts and bolts shall be mild steel hot dip galvanised. GS spring washers shall be provided for making satisfactory joints. Clamps splice plates etc. shall be provided wherever necessary.

Whenever the outdoor portion of the bus duct is of flanged construction but of bolted type a continuous hood made of non-magnetic material shall be provided over the entire length of the outdoor portion of the bus duct to prevent ingress of water particles due to heavy rain fall directly on bus duct enclosure. This hood shall be mounted on bus duct supporting structures and all hardware and accessories required for mounting the hood shall be furnished by the VENDOR.

8.13.2 Bus Conductor

The material of the conductor shall be of Copper. The grade of copper shall be indicated by the BIDDER.

The temperature rise of conductor shall be as per IS: 8084. Also the temperature of the bus shall not exceed 250°C while carrying the specified short circuit current for one second when a fault occurs at the operating temperature.

The bus conductor shall be given a coat of matt black paint to facilitate heat dissipation. The bare conductor with above painting shall be designed to carry the normal rated current without exceeding temperature rise as specified in IS: 8084

Flexible copper connectors connected to the main busbars shall be provided wherever deemed necessary.

The connectors shall be of the same material as the conductor and joints shall be silver-plated to ensure an efficient connection. The bolting schedule and contact pressure shall conform to accepted codes of practice.

Flexible braided copper connections shall be provided at the equipment terminal connections. The joints shall be capable of 25 mm settlement of the equipment mounting pads. The joints shall be suitably designed to take care of the vibration at the terminals as well as the expansion and contraction of the busbars.

Expansion joints made of copper strips shall be provided wherever deemed necessary, to take care of expansion and contraction of the busbars under normal operating conditions.

All the above joints shall be tested for temperature rise to prove the adequacy of the design. The maximum temperature rise at the joints shall be less than the specified temperature rise for the busbars.

The busbar clamps at insulators shall be designed to withstand the forces due to momentary short circuit current. They shall permit free longitudinal movement of the bus bars during expansion and contraction. The material of the clamps shall be copper. Suitable spacers shall be provided wherever necessary.

All bolts, nuts and lock washers used in the bus assembly shall be of high tensile steel, plated for corrosion resistance. Spring washers of "Beleville" type or equivalent shall be used.

Suitable splice plates and connectors shall be provided wherever necessary.

Disconnecting links with rating same as that of the main busbars shall be provided in the run of the bus duct to facilitate disconnection of the busbars during testing and maintenance. The separation of the busbar sections with the bolted links removed shall be sufficient to withstand the rated voltage of the bus duct.

Shorting jumpers, for the purpose of drying out the equipment before commissioning or for carrying out short circuit test on the equipment, rated for the main bus current shall be supplied for shorting the bus duct at a location, adjacent to the disconnecting links.

The shorting links shall have drilling dimensions matching those of the main bus disconnecting links. Suitable supporting structures and support insulators for the shorting links if necessary shall also be offered.

8.13.3 **Phase Barriers**

In segregated phase bus duct if metal barriers are provided, the material shall be same as that of the bus duct enclosure material.

Insulated phase barriers, when specified, shall be made of non-hygroscope insulating material such as fibre glass.

8.13.4 **Bus Support Insulators**

Within the bus duct the bus shall be mounted and supported on insulators. The insulators shall be mounted on resilient pads provided in the bus enclosure.

The insulators shall be either porcelain or resin cast.

For bus ducts with voltage rating up to 1100 Volt, Fibre glass/FRP or equivalent type of non-hygroscope insulating supports are acceptable.

8.13.5 Wall Frame Assembly and Seal – off Bushing

Wherever the bus duct passes through the plant building wall, from indoors to outdoors, a wall frame assembly with seal-off bushings shall be provided to prevent any leakage of rain water, infiltration of dust and air temperature variations from indoors to outdoors. The wall frame shall be fabricated out of aluminium angles and sheet and shall be suitable for grouting in the wall. It shall be provided with flanges on both sides to receive the bus duct flanges. A suitable size breather shall be provided for the two sections of the busduct between the wall frame assembly.

The bus duct shall be equipped wherever necessary with seal-off bushings to prevent interchange of air at different temperatures. The seal-off bushings shall be flanged type.

The insulator for wall frame assembly and seal-off bushings shall be of porcelain. Also the bushings shall be designed for thermal expansion/contraction due to temperature differential for outdoor/indoor use.

8.13.6 Bus Duct Supports

The supporting structure shall be fabricated from standard steel sections and shall be hot dip galvanised after fabrication. The hot dip galvanising shall be in accordance with standards.

Calculations shall be furnished to substantiate the strength support structure to withstand the various static and dynamic loadings.

The supporting structures shall include supporting members, brackets, hangers, longitudinal beams, channels, nuts, bolts, washers and all other hardware which are necessary for the erection and support of the entire bus duct installation. All the accessories and hardware of ferrous material shall be hot dip galvanised.

Studs, nuts, bolts and tapped holes shall conform to the relevant standards. Only hexagonal nuts shall be used. All bolt holes shall be spot faced for nuts.

Castings and forgings shall conform to respective material specifications and shall be free from flaws. They shall be machined true as per good workshop practice. Welding shall be performed in accordance with relevant recognised standards.

All threaded pipe connections and fittings, pipe flanges and tube fittings shall comply with relevant standards.

Indoor portion of the bus duct may be supported from the floor or ceiling beams.

Outdoor portion of the bus duct shall be supported from ground below on suitable foundation in the ground.

The foundations and structures in outdoor area shall clear the transformers, transformer foundations, cable trenches.

Each supporting structure shall be securely connected at two points to the station earthing bus. Earthing of enclosure to support structures shall be securely connected at two ends of busduct. All necessary hardware, such as clamps, connectors, etc. required for this purpose shall be furnished by the VENDOR.

8.13.7 **Design Calculations to be submitted**

The vendor shall submit following design calculations:

- Sizing of the busbars vis-à-vis thermal capability to withstand rated continuous current and one second short time current.
- Spacing of the insulators vis-à-vis mechanical strength to withstand forces due to momentary short circuit current.
- Heat loss and temperature rise calculations for conductor and enclosure. All formulae and other information from which the heat losses have been derived shall be enlisted.

8.13.8 **Technical Particulars**

The specific technical particulars of Bus Duct shall be as given in the table below:

Sl. No	**Description**	**Particulars**
1	Type of Bus Duct	Non-Segregated
2	Type of Cooling	Naturally Air Cooled
3	Installation	Indoor / Partially Outdoor
4	Nominal Service Voltage	415V
5	Rated Voltage Class	1.1kV
6	Continuous Current Rating of Bus Ducts under Site Conditions	(*)
7	One minute Power Frequency Withstand Voltage	3.0 kV (Peak)
8	Momentary Current Rating	125kA (Peak)
9	Short Time Current Rating for one second - kA (RMS)	(*)
10	Maximum Temperature (Hot Spot) of Busbars at Rated Current - °C	85 ^{0}C

Sl. No	Description	Particulars
11	Maximum Temperature (Hot Spot) of Enclosure at Rated Current °C	Not to exceed 70 ^{0}C
12	Busbar Material	Copper
13	Busbar Section	Rectangular section
14	Bus Enclosure Material	Aluminium Alloy
15	Shape of Enclosure	Rectangular
16	Phase Clearance (Minimum) Phase to Phase mm Phase to Earth mm	AS per relevant standards
17	Type of Joints between Adjacent Sections of Bus Conductor Welded/Bolted	Bolted

8.14 Electric Motors

8.14.1 General

Electric motors shall comply with IS 325, 4029, 4722, BS 4999 and BS 5000, IEC 60034, IEC 60072 and IEC 60085 including standards referred to therein and shall be bi-directional and rated on the basis of duty type S1 (maximum continuous rating). The submersible motor shall conform to IS: 325/IS: 9283 and the submersible cable shall conform to IS: 9968. The motor shall be three phase dry induction type with non-overloading characteristics.

Where the power supply permits motors shall be preferentially of the 3 phase type.

Motors shall be suitable for two starts in succession from hot under the specified duty conditions of load torque and inertia and shall also be suitable for six equally spaced starts per hour under similar conditions.

Motors shall be designed to operate on the supply voltage specified for the Works.

Motors shall be capable of operating under conditions of three phase supply imbalance where the negative and zero phase sequence components of the voltage do not individually exceed 2% of the positive phase sequence components.

8.14.2 Performance and Characteristics

8.14.2.1 *The technical parameters of main MV motors*

Description	Unit	Particulars
Type		Squirrel cage Induction motor (TETV or CACA)
Rating	kW	(*)
Rated voltage	kV	3.3

Description	Unit	Particulars
Type of mounting		As per requirement
Duty type		Continuous (S1)
Method of starting		By soft starter (Line or Neutral side)
Type of system earthing		Earthed through resistance to limit the earth fault current to 1000 A.
Class of insulation		F
Design ambient temperature	°C	50
Efficiency class		Energy efficient Eff1 or Eff2 (Certification required)
Limits of temperature rise of winding		
- Determination by resistance method	°C	70
- Determination by ETD method	°C	80
Location		Indoor
Degree of Protection		IP55
Cooling designation		IC411
Terminal box		Two terminal boxes (on opposite sides)
External cable details		3.6 / 6 kV, 3C x (*) Aluminum, XLPE, armoured
Space heater for motor		Required

(*) Value to be ascertained by the Contractor after submitting design calculations subject to approval

8.14.2.2 *The technical parameters of LV motors*

Description	Unit	Particulars
Type		Squirrel cage Induction motor (TEFC)
Rating	kW	(*)
Rated voltage	kV	0.415
Type of mounting		Vertical / Horizontal (As required)
Duty type		Continuous (S1)
Method of starting		Direct on line- for motors upto 5.5W Star-Delta – For motors above 5.5kW upto 75kW Soft Starter – For motors above 75kW
Type of system earthing		Effectively earthed

Description	Unit	Particulars
Class of insulation		F
Design ambient temperature	°C	50
Efficiency class		Energy efficient Eff1 or Eff2 (Certification required)
Limits of temperature rise of winding		
- Determination by resistance method	°C	70
- Determination by ETD method	°C	80
Location		Indoor
Degree of Protection		IP55
Cooling designation		IC411
External cable details		1.1 kV, 3C x (*) Aluminum, XLPE, armoured
Space heater for motor		Required for rating 30kW and above

(*) – To be furnished by Contractor. Contractor should ensure that all the equipment ratings are based on their system requirement and subject to Engineer approval.

Motors rating up to and including 5.5 KW shall be started by DOL starter, Motor ratings above 5.5KW and up to or equal to 75 KW shall be started by Star-Delta Starter and above 75 KW shall be started by soft starter.

Motors shall be energy efficient (Category –2 or better) squirrel cage induction motors (TEFC type for LV motors and TFTV type for MV motors) with degree of protection for enclosure of IP 55 for external use and IP68 for submersible used.

Motor shall be capable of starting and accelerating the load for the method of starting, without exceeding acceptable winding temperatures, when the supply voltage is 80% of the rated voltage. Main conductor and insulation shall be non-hygroscopic and in accordance with Class F of IEC 60085.

Motors shall be capable of giving rated output without reduction in the expected life span when operated continuously under the following supply conditions:

Variation in supply voltage	±10%
Variation in supply frequency	±5%
Combined voltage and frequency variation	±10%

The starting current of motor shall not exceed 200% of rated full load current for star/delta starting and 600% of rated full load current for DOL starting, under any circumstances.

Motors shall be designed to withstand 120% of rated speed for two minutes without any mechanical damage, in either direction of rotation.

The motor vibrations shall be within the limits specified in the relevant standard.

Minimum three number thermistors in series are to be provided to sense the stator winding temperature.

Bimetallic thermal switch to trip the motor against increase in temperature shall be provided.

The power rating of the motor shall be larger of the following:

115% of the power input to the pump at duty point.
105% of the power input to the pump at 75% head.

Motors shall withstand the voltage and torque stresses developed due to the vector difference between the motor residual voltage and the incoming supply voltage equal to 150% of the rated voltage, during fast changeover of buses. The duration of this condition is envisaged for a period of one second.

The locked rotor withstand time under hot conditions at 110% rated voltage shall be more than the starting time at minimum permissible voltage by at least two seconds or 15% of the accelerating time, whichever is greater. The locked rotor current of motors shall not exceed 600% of full load current of motor which is inclusive of 20% tolerance.

The motors shall be provided with class F insulation with temperature limited to that of class B insulation.

8.14.3 **Submersible Cable**

The cable shall be EPR insulated, CPS sheathed, round, multi core, flexible, unarmored, conductors composed of annealed tinned copper, suitable for 650 / 1100 volts grade and conforming to IS: 9968.

The size of the conductor and length of cable should be suitably selected so that the voltage drop at motor terminals does not exceed 3 percent of the rated voltage.

8.14.4 **Earthing**

Earthing of the motor shall be done in accordance with the relevant provisions of IS: 3043:1966.

8.14.5 **Insulation**

The stator winding shall be made from high conductivity annealed copper conductor; winding insulation shall be of class-F insulation, conforming to IS: 325. The stator winding shall be of high conductivity annealed copper enamelled insulated wires conforming to IS: 4800 (Part-VII): 1970 for dry type motors.

8.14.6 **Constructional Features**

Motors weighing more than 25 kg shall be provided with eyebolts, lugs or other means to facilitate safe lifting.

The motor construction shall be suitable for easy disassembly and re-assembly. The enclosure shall be sturdy and shall permit easy removal of any part of the motor for inspection and repair.

The rotor bars shall not be insulated in the slot portion between the inner core laminations for squirrel cage motors.

All bearings shall be fitted with oil or grease lubricators. Motor bearings shall not be subjected to any external thrust load. Unless otherwise specified, motor bearings shall have an estimated life of at least 40,000 hrs. It shall be possible to lubricate the bearings without dismantling any part of the motor. All terminals shall be of the stud type of adequate size for the particular duty, marked in accordance with an approved standard and enclosed in a weatherproof box.

The equipment shall be thoroughly degreased, all rust, sharp edges and scale removed and treated with one coat of primer and finished with two coats of grey enamel paint.

The motor shall be suitable for continuous duty as well as intermittent duty with or without full submergence of the motor.

Aluminium die cast rotor to be provided for better starting torque characteristics.

The electric motor shall be suitable for 10 starts & stops per hour.

Single phasing and overload protection system shall be provided.

Junction box (i.e.) for terminating power & control cables for each motor.

Motor construction shall provide a degree of protection as follows:

IP 54 - internal use including applications in dusty environments.

IP 55 - external use in exposed locations.

IP 68- submersible use

Motor mounting arrangement shall be to suit application.

Motors shall be designed for normal sound power as defined by IS 325 or BS 4999.

Windings shall be insulated to class F as defined by IS 11182 or BS 2757. However, temperature rise at full load shall be limited to that for Class B insulation.

Where specified motor windings shall incorporate:

thermistors (PTC type), or

resistance thermometers (PT 100).

In each instance the temperature detecting devices shall be in close thermal contact with each phase of the stator windings. All thermistors shall be connected together to provide a single electrical circuit for connection to an external relay which will be capable of tripping the motor.

Each resistance thermometer shall be connected separately to an external monitor relay which shall offer alarm and trip settings. Thermal protection shall be Class 1 for sizes of motor of 75 kW and below and Class II above 75 kW.

All HV motors shall be fitted with anti-condensation heaters. A warning label, black letters on a yellow background shall be fitted to indicate that the heater may be energised. Heater terminals shall be shrouded. On larger motors a separate terminal box shall be provided.

Anti-condensation heaters shall be sized to raise the temperature inside the motor several degrees above the dew point temperature. The heater surface temperature should not exceed 200°C.

Heaters shall be automatically disconnected when the motor is switched on.

8.14.7 **Terminal Box**

Terminal boxes shall be of weatherproof construction designed for outdoor service. To eliminate entry to dust and water, gaskets of neoprene or approved equivalent shall be provided at cover joints and between box and motor frame. It shall be suitable for bottom entry of cables. It shall be capable of being turned through 360 degree in steps of 90 degree.

The terminals shall be of the stud type with necessary plain washers, spring washers and check-nuts. They shall be designed for the current carrying capacity and shall ensure ample phase to phase and phase to ground clearances. Suitable cable glands and cable lugs shall be supplied.

Separate terminal boxes shall be provided for each of the following:

Stator Leads

Space Heaters

8.14.8 **Accessories**

8.14.8.1 *Drain Plugs*

Motors shall be provided with drain plugs, so located to drain water, resulting from condensation or due to other causes, from all pockets in the motor casing.

8.14.8.2 *Heating during Idle Period*

For motors rated below 30 kW, during idle periods, the stator winding shall be connected to required single phase, 50 Hz, 230AC supply for heating and elimination of moisture. The supply shall be connected between any two terminals.

Motors rated 30kW and above shall have space heaters suitable for 230V, single phase, 50 Hz, AC supply. Space heaters shall have adequate capacity to maintain motor internal temperature above dew point to prevent moisture condensation during idle period. The space heaters shall be placed in easily accessible positions in the lowest part of the motor frame.

8.14.8.3 *Earthing Pad*

Two independent earthing pads of non-corrodible metal shall be welded or brazed at two locations on opposite sides complete with suitable bolt and washers for earthing. These earthing pads shall be in addition to earthing stud provided in the terminal box.

8.14.8.4 *Rating Plate*

The following details, in addition to those specified in applicable standards shall be included on the rating plate.

> Rated voltage, kW rating, frequency, efficiency, power factor, temperature rise of windings in degree centigrade at rated load, and ambient conditions.
>
> Type of bearings, recommended lubricant, lubricating interval & re-lubricating quantity.

8.14.9 **Tests**

Motor shall be subjected to all the type test (one from similar rating of each lot) and routine tests as per applicable standard, in the presence of the Engineer. Copies of test certificates for all brought out items shall be furnished at the time of inspection for the Employer's approval. The Contractor shall ensure to use calibrated test equipment / instruments having valid calibration test certificates from standard laboratories traceable to National / International standards.

8.15 Variable Frequency Drives (VFD)

8.15.1 **General**

AC induction motor in clear water pumping station for rural distribution shall be coupled with a Frequency drive of rating commensurate with the rated motor. The Frequency drives shall be of Voltage Source Inverter Pulse Width Modulated (VSIPWM) with GTO/IGBT/IGCT/SGCT/DTC technologies or later version, which performs precise speed and torque control of standard squirrel cage motors with optimum efficiency. All frequency dives shall be suitable for data connectivity with PLC/SCADA system and shall have suitable communication port and protocol. The drives must be easily programmable. The drives shall be provided with surge protection, programmable lockable code. The Frequency drive shall have following characteristics:

- Accurate open loop torque control
- Torque step rise time typically less than 5 ms
- Speed control inaccuracy typically 0.1% to 0.5% of nominal speed
- 150% overload capacity for 60 second

Total Harmonic distortion shall comply with the provisions of IEEE 519. Necessary metering, self-diagnostic arrangement (including display and alarm facilities) shall be provided for local/ remote monitoring.

8.15.2 Technical parameters

Main connection

Voltage	:	3 phase, 415 +/- 10 % permitted tolerance
Frequency	:	45 to 65 Hz, maximum rate of change 17%/s
Imbalance	:	Max. +/- 3% of nominal phase to phase input voltage
Fundamental Power factor	:	0.97 (at nominal load)

Motor connection

Voltage	:	3 phase, from 0 to applied incoming supply voltage, 3-phase symmetrical
Output Frequency	:	0 to 250 Hz
Frequency Resolution	:	0.01 Hz
Continuous Current	:	1.0 * I2N(normal use)
Short Term Overload Capacity (1min./10min)	:	I2max = 1.1 * I2N
Field Weakening point	:	8 to 300 Hz
Acceleration Time	:	0 to 1800 sec
Deceleration Time	:	0 to 1800 sec
Efficiency	:	Min. 97% at nominal power level

Environment limits

Ambient temperature	:	0 to 45 deg. Cent.

Standard control connections

- 3 programmable differential analogue inputs (1 voltage signal, 2 current signals)
- 7 programmable digital inputs
- 2 programmables analogues outputs (current signal)
- 3 programmable digital outputs (from C relays)
- Optional analogue and digital extension modules can be added as well as a wide range of field bus adapters.

Protection

- Over current

- Short circuit at start-up
- Input phase loss
- Output phase loss
- Motor overload
- Earth fault
- Overvoltage
- Under voltage
- Over temperature
- Motor stall

Application macros

The features a selection of built-in, pre-programmed application macros for configuration of inputs, outputs, signal processing and other parameters. It shall have interfacing facilities to communicate data to SCADA system. These include:

- FACTORY SETTING for basic industrial applications
- HAND/AUTO CONTROL for local and remote operation
- PID CONTROL for closed loop processes
- TORQUE CONTROL for process where torque control is required.
- SEQUENTIAL CONTROL for processes where torque control is required.
- USER MACRO 1 and 2 for user's own parameter setting
- Comprehensive testing and diagnostic function

8.15.3 Tests

Each unit of Variable frequency drive shall be tested at the manufacturer's work. Test result must satisfy the efficiencies on various loads and at different frequency levels against their quoted values during bidding.

8.16 Soft Starters for MV and LV Motors

MV Soft Starter particulars

Description	**Unit**	**Particulars**
Type, Application and criteria for sizing		Clear Water Distribution Pumps (Starting current to be limited to 2.5 to 3 times the rated current of the motor)

Description	Unit	Particulars
Connection		On phase/neutral side of stator winding
Quantity	Nos.	Distribution Pump Stations
Rated voltage	kV	3.6 for MV
Rated lightning impulse withstand voltage		
- Across the isolating distance	kV (peak)	70
- Phase to phase, between phases and across open switching devices	kV (peak)	60
Rated short duration power frequency withstand voltage		
- Across the isolating distance	kV (rms)	23
- Phase to phase, between phases and across open switching devices	kV (rms)	20
Installation		Indoor
Enclosure		
- Sheet steel thickness	mm	2
- Degree of protection		IP4X
- Color finish shade		Light Grey Semi Glossy
External cable details		3.6 / 6 kV, 3C x (*) Aluminum, XLPE, armoured
Type of cooling		Air cooled
Bypass arrangement	Required	By Vacuum contactor/Built-in with soft starter
Control supply	V	110V DC / 230 V AC as required for the control

LV Soft Starter particulars

Description	Unit	Particulars
Type, Application and criteria for sizing		Pumps and Blowers (Starting current to be limited to 2.5 to 3 times the rated current of the motor)

Description	**Unit**	**Particulars**
Connection		On phase/neutral side of stator winding
Rated voltage	kV	0.415 for LV
Rated lightning impulse withstand voltage		
- Across the isolating distance	kV (peak)	46
- Phase to phase, between phases and across open switching devices	kV (peak)	40
Rated short duration power frequency withstand voltage		
- Across the isolating distance	kV (rms)	12
- Phase to phase, between phases and across open switching devices	kV (rms)	10
Installation		Indoor
Enclosure		
- Sheet steel thickness	mm	2
- Degree of protection		IP4X
- Color finish shade		Light Grey Semi Glossy
External cable details		3.6 / 6 kV, 3C x (*) Aluminum, XLPE, armoured
Type of cooling		Air cooled
Bypass arrangement	Required	By Vacuum contactor/Built-in with soft starter
Control supply	V	110V DC / 230 V AC as required for the control

(*) Value to be ascertained by the Contractor after submitting design calculations subject to approval.

8.16.1 **Constructional and Performance Features**

Motor soft starters shall be switched reactance type or flux compensated type or electronic type.

Soft starter panel shall be indoor, metal clad with separate metal enclosed compartments for

a) control, metering and current transformers for differential protection, if specified

b) shorting (bypass) arrangement

c) bus bars

d) power cable terminations

e) push buttons with indicating lamps.

Soft starter shall achieve soft starting by torque control for gradual acceleration of the drive thus preventing jerks and extending the life of equipment.

Starting current shall be limited to 2.5 to 3 times the rated current of the motor. The soft starter manufacturer shall co-ordinate with motor manufacturer for this purpose.

Separate removable gland plates shall be provided for power and control cables.

Each cubicle shall be fitted with a label in the front and rear of the cubicle, indicating the panel designation, rating and duty. Each relay, instrument, switch, fuse and other devices shall be provided with separate labels.

Necessary wiring diagram shall be provided considering starting interlock, trip circuit, starting and running mode signal.

It shall be possible to manually start the motor locally from the starter panel or in Auto mode through PLC.

8.16.2 **Main Bus bars**

Bus bars shall be fully insulated by encapsulation in epoxy resin, with moulded caps protecting all joints. Bus bars shall be supported on insulators capable of withstanding dynamic stresses due to short circuit. Bus bars shall be of hard drawn copper conductor and of high conductivity, EC grade copper of 99.7% purity.

8.16.3 **Earthing**

A copper earthing bus shall be provided at the bottom and extended throughout the length of the panel. It shall be bolted / welded to the framework. All non-current carrying metal work of the panel shall be effectively bonded to the earth bus. Hinged doors shall be earthed through flexible earthing braid.

8.16.4 **Panel Accessories and Wiring**

Panel shall be supplied completely wired internally up to equipment and terminal blocks and ready for the external cable connections at the terminal blocks. Inter panel wiring between compartment of the same panel shall be provided.

All auxiliary wiring shall be carried out with 1100 volts grade, single core, stranded copper conductor with PVC insulation. The sizes of wire shall be not less than 1.5 sq. mm.

Terminal blocks shall be of stud type, 10 A rated, complete with insulated barriers. Terminal blocks for CTs shall be provided with test links and isolating facilities.

All spare contacts and terminals of cubicle mounted equipment and devices shall be wired to terminal blocks.

Accuracy class for indicating instruments shall be 1.0 or better. Instruments shall be 110 mm square, 240^0scale for flush mounting with only flanges projecting.

Push buttons shall be provided with inscription plates engraved with their functions. Indicating lamps shall be of clustered LED type. Space heaters of adequate capacity shall be provided inside each panel. They shall be suitable for 230 V, 1 ph, 50 Hz supply. They shall be complete with MCB and thermostat.

Each panel shall be provided with 230 Volts, 1 phase, 50 Hz, 5 A, 3 pin receptacle with MCB located in a convenient position. An interior illuminating lamp together with the operating door switch and protective MCBs shall be provided.

The DC and AC auxiliary supply shall be distributed inside the panel with necessary isolating arrangements at the point of entry and with sub-circuit MCBs as required.

8.16.5 **Tests**

Each unit of soft starter shall be tested as per relevant standards at the manufacturer's work. Test result must satisfy all the characteristics during starting and acceleration against their quoted values during bidding.

8.16.6 **Cable Terminations**

Cable termination boxes shall be suitable for air termination of cables. They shall be sealed with a neoprene gasket to provide dust and weather protection.

Cable boxes for voltages in excess of 1 000 V shall be treated with anti-tracking varnish.

8.17 Neutral Earthing Resistor

Neutral earthing resistors shall comply with IEEE 32 including those standards referred to therein.

8.17.1 **The technical parameters of Neutral earthing resistors**

Description	**Unit**	**Particulars**
Application and criteria for sizing		For earthing of main transformer neutral and to limit the earth fault current on secondary side to 1000 A
Quantity	Nos.	2
Material of resistor		Wire wound – Stainless steel
Installation		Outdoor, Insulator mounted

Description	Unit	Particulars
Enclosure		
- Sheet steel thickness	mm	2
- Degree of protection		IP 34
- Color finish shade		Light Grey Semi Glossy
Type of cooling		Natural air cooled
Rated voltage	kV	3.6
Rated current	A	1000
Ohmic value	Ohm	(*)
Rated time	sec	10

(*) Value to be ascertained by the Contractor after submitting design calculations subject to approval.

8.17.2 Resistor Element

The element material shall possess a balanced combination of properties, uniformity of resistance and mechanical stability over the intended temperature range, without any injurious effects on the elements and its associated insulation.

The resistor assembly shall be designed for a maximum temperature rise as per IEEE 32, Table 6, Column 7. The maximum operating temperature shall not be higher than 80% of the maximum design temperature.

8.17.3 Construction

The construction of the resistor assembly shall be such that the minimum required insulation resistance is available under all atmospheric conditions. A space heater shall be provided, if necessary. The minimum degree of protection for the resistor enclosure shall be IP-54.

The front and back covers shall be removable for access to internal resistor connection and for removal of resistor banks.

The resistor shall be housed in a free standing and self-supporting metal enclosure suitable for installation in outdoor, extreme climatic conditions.

The enclosure shall be suitable for mounting on insulators fixed on a 2.5m high structure.

The resistor elements and the cable and earthing termination connection shall be insulated from the enclosure.

The main and earth connection boxes and terminals shall be suitable for the cable specified and adequate space shall be provided for termination of cables.

All cable terminations shall be bolted. Low melting alloys used to join connectors, which would be adversely affected by the resistor operating temperatures, shall not be used. All conductor terminations must be mechanically secured to provide continuous electrical continuity.

Terminal box shall have a degree of protection of IP 55.

Cable gland plates shall be made of non-magnetic material.

8.17.4 **Tests**

Type and routine test certificates as per relevant standards including Quality Assurance Plan (QAP) for neutral grounding resistors shall be submitted for Employer Representative’s approval.

8.18 Lighting System Installation, Testing and Commissioning Work

8.18.1 **Applicable standards**

Lighting	IS:6665
Calculation of co-efficient of utilisation	IS:3646 (Part - III)
Industrial lighting fittings with metal reflectors	IS:1777
Decorative lighting outfits	IS:5077
Dust proof electric lighting fittings	IS:4012
Dust tight electric lighting fittings	IS:4013
Flood lights	IS:10322/BS:4533
Luminaires for street lighting	IS:10322 Part 5
Water tight electric lighting fittings	IS:3553/BS:4533,5225(I)
Bayonet lamp holders	IS:1258/BS:EN 61184/IEC:61
Edison screw lamp holders	IS:10276/BS:EN 60238
Bi-Pin lamp holders for tubular fluorescent lamps	IS:3323
Starters for fluorescent lamp	IS:2215/BS:EN 60155
Holders for starters for tubular fluorescent lamps	IS:3324/BS:EN 60400/IEC:400
Ballast for use in fluorescent lighting fittings	IS:1534 (Part 1)/BS:EN 60920 and 60921/ IEC:82
Transistorised ballast for fluorescent lamps	IS:7027
Ballast for HP mercury vapour lamp	IS:6616
Capacitors for use in fluorescent, HPMV & LP sodium vapour discharge circuits	IS:1569/BS:EN 61048 and 61049/IEC:586

Vitreous enamel reflector for tungsten filament lamp	IS:8017
Tubular fluorescent lamps	IS:2418 (Part1)/BS:EN 60081/IEC:81
High pressure mercury vapour lamps	IS:9900/BS:3677/IEC:188
Tungsten filament general electric lamps	IS:418/IEC:432
Cast acrylic sheets for use in Luminaires	IS:7569
Screwless terminal and electrical connections for lighting fittings	IS:10322
High pressure sodium vapour lamps	IS:9974
Emergency lighting units	IS:9583
Ignition proof enclosures, dust-tight for	IS:11005
Elect. Equipment Luminaires (Part I to V)	IS:10322
Arrangement for busbars, main connection sand auxiliary wiring and marking	IS:5578/11353/BS:159
Enclosed distribution fuse boards and cutouts for voltages not exceeding 1000V	IS:2675/BS-EN 60439
General requirements for switchgear and control gear for voltages not exceeding 1000 V	IS:13947
Code of practice - installation and maintenance of switchgear	IS:10118/BS:6423
Factory built assemblies of switchgear and control gear for voltages up to and including 1000 V AC and 1200 V DC	IS:8623/BS-5486/IEC:439
Miniature air break circuit breakers for AC circuits	IS:8828/BS:EN 60898
HRC cartridge fuse links up to 650 V	IS:9224/BS:88/IEC:269
'D' Type fuses	IS:8187
Current transformers	IS:2705/BS:7626/IEC:185
Voltage transformers	IS:3156/BS:7625/IEC:186
Direct acting electrical indicating	IS:1248/BS:89/IEC:51
Instruments a.c.. electricity meters	IS:722/BS:5685
Switches for domestic and similar purposes	IS:3854/BS:3676
Three pin plugs and socket outlets	IS:1293/BS:546
Boxes for enclosure of electrical accessories	IS:5133(1)
Rigid steel conduits for electrical wiring	IS:9537/BS:31

Accessories for rigid steel conduits for electrical wiring	IS:3837/BS-31
Flexible steel conduits for electrical wiring	IS:3480
Rigid non-metallic conduits for electrical installations	IS:9537/BS:4607(2)
Fittings for rigid non-metallic conduits	IS:3419/BS:4607(2)
PVC insulated cables for working voltages up to and including 1100 V	IS:694
Tubular steel poles	IS:2713
Wrought aluminium and aluminium alloys, bars, rods, tubes and sections for electrical purposes	IS:5082/BS:2898
Code of practice for phosphating iron and steel	IS:6005/BS:3189
Fittings for rigid steel conduits for electrical wiring	IS:2667
Electrical wiring installations (system voltage exceeding 650 V)	IS:732
Code for practice for interior illumination	IS:3646/BS:8206 (Part-1)
Code of practice for street lighting installation	IS:1944
Code of practice for industrial lighting	IS:6666
Code of practice for fire safety of building	IS:1646
Boxes for enclosure of electrical accessories	IS:5133 (Part-1)
Guide for safety procedures and practices in electrical work	IS:5216
Ceiling roses	cIS:371

8.18.2 Lighting Fixtures (Luminaires)

Luminaires shall be energy efficient and designed for continuous trouble-free operation without reduction in lamp life or without deterioration of materials and internal wiring. Fixtures shall be energy efficient and ballast shall be electronic low loss type. All indoor lighting fixture for office and control room shall be decorative type and for remaining areas it shall be industrial type. Outdoor fittings shall be weather-proof and rain-proof type.

The luminaires shall be designed so as to facilitate easy maintenance, including cleaning, replacement of lamps/starters etc.

Connections between different components shall be made in such a way that they will not work loose by small vibration.

All luminaires shall be supplied complete with lamps suitable for operation on a supply voltage and the variation in supply voltage and frequency indicated in the Employer's Requirements.

Fluorescent type, LED type, mercury vapour and sodium vapour type Luminaires shall be complete with accessories like lamps, ballasts, power factor improvement capacitors, starters, re-wireable fuse and fuse base. These shall be mounted as far as possible in the luminaire housing only. If these cannot be accommodated integral with the Luminaires then a separate metal enclosed control gear box shall be included to accommodate the control accessories together with a terminal block suitable for loop-in, loop-out connections. Outdoor type fixtures shall be provided with outdoor type weather-proof box.

Fluorescent type luminaires with more than one lamp shall be provided with capacitors connected in lead-lag circuit for correction of stroboscopic effect.

Each luminaire shall have a terminal block suitable for loop-in, loop-out and T-off connection by 250/400 V, 1 core, PVC insulated copper/aluminium conductor wires up to 4 sq.mm in size. In outdoor areas the termination at the luminaire shall be suitable for 1100 V, PVC insulated, copper/aluminium conductor, armoured cables of sizes up to 6 sq.mm conductor. Terminals shall be of stud or clamp type. The internal wiring shall be by means of insulated copper wire of minimum 1 sq.mm size and terminated on the terminal block. Terminal blocks shall be mounted with minimum two fixing screws.

Mounting facility and conduit knock-outs for the luminaires shall be provided.

8.18.3 Earthing

Each luminaire and control gear box shall be provided with an earthing terminal.

All metal or metal enclosed parts of the luminaire/control gear box shall be bonded and connected to the earthing terminal so as to ensure satisfactory earthing continuity.

8.18.4 Painting/Finish

All surfaces of the luminaire/control gear box housing accessories shall be thoroughly cleaned and degreased. It shall be free from scale, rust, sharp edges and burrs. The luminaire housing shall be stove-enamelled/epoxy stove-enamelled-vitreous enamelled or anodised as indicated under various types of fittings.

8.18.5 Decorative Fluorescent Luminaires

Fluorescent luminaires shall be generally indoor type provided with cold rolled cold annealed (CRCA) sheet steel channel/rail cum reflector housing complete with all electrical control accessories mounted on it. The finish shall be stove enamelled.

Decorative fluorescent type luminaires shall be either open type, provided with translucent white opal acrylic diffusers, polystyrene lens prismatic or square polystyrene louvers.

Luminaires shall be suitable for the number of lamps of specified wattage, direct mounting on ceiling/wall/column pendant mounting or for recess mounting in false ceiling.

Decorative luminaires with mirror optic reflectors shall be of the wide angle dispersion type.

Where these luminaires are mounted in control rooms and computer rooms, clip-on type adjustable reflectors which can be attached onto the tube shall be provided to direct the light output in the desired direction. This is mainly to reduce reflection of the light source from TV/monitor screens.

Luminaires mounted recessed in false ceiling shall be with reflector housing and spring loaded fixing arrangement for the diffuser/louver frame. It shall be possible to have access to the lamp and other accessories from below.

8.18.6 **Industrial Luminaires**

8.18.6.1 *Fluorescent Luminaires*

The luminaire shall be provided with CRCA sheet steel mounting rail with reflector of minimum 20 SWG thickness and complete with all control accessories mounted on it. The finish shall be vitreous enamelled.

Luminaires shall be suitable for the number of lamps of specified wattage, direct mounting on ceiling/wall/column/pendent mounting.

The distribution of light shall be such that at least 80% of the total luminous flux from the luminaire shall be in the lower hemisphere.

The luminous output of the luminaire with reflector shall not be less than 75% irrespective of type of reflector used.

Luminaires for use in areas where chlorine is stored or dosed shall be fully enclosed to IP65 and have a luminaire body constructed of GRP or some other non-metallic material resistant to attach by chlorine.

8.18.6.2 *Incandescent/Mercury Vapour/Sodium Vapour Luminaires*

The luminaire shall be of robust construction, with cast aluminium/vitreous enamelled housing, heat and shock resistant prismatic or clear glass cover fixed with neoprene gaskets for sealing. For mechanical protection to the glass cover, round steel wire-guard with vitreous enamelled finish shall be provided.

The luminaire shall be suitable for incandescent lamp up to 150 watts, for direct mounting to ceiling/wall/column and used for general purpose indoor lighting.

8.18.6.3 *High and Medium Bay Luminaires*

High and medium bay luminaires shall be with cast aluminium housing, anodised aluminium mirror polished reflector canopy with eye bolt for suspension, cooling fins and glass cover.

The luminaire shall be suitable for mercury vapour lamps up to 1000 watts and sodium vapour lamps up to 400 watts. The control gear accessories shall be mounted integral with the luminaire.

High bay luminaires shall be used when the mounting height is above 8 metres while medium bay luminaires shall be used when the mounting height is around 6 to 8 metres.

8.18.7 **Flood Light Luminaire**

Flood light luminaires shall be of weather proof construction with cast aluminium housing, anodised aluminium mirror polished reflector, heat resistant, toughened glass cover and necessary neoprene gaskets to prevent ingress of dust.

The housing shall be supported on a cast iron base and capable of being swivelled in both horizontal and vertical directions and locked in any desired position.

For focusing purposes, knobs, shall be provided along with sector plate indicating the angle in degrees between 0 and 90 degrees. in vertical direction.

The Luminaires shall be suitable for single and dual mercury vapour or sodium vapour lamps up to 400 watts, incandescent lamps up to 1000 watts or halogen lamps up to 1000 watts. When mercury vapour or sodium vapour lamps are specified, the same shall be mounted in a separate sheet metal enclosed/cast aluminium weather proof control gear box.

The luminaire shall be provided with cable gland on the canopy in down ward direction for cable connection.

It shall be possible to adjust the lamp position to achieve wide beam, medium beam or narrow beam.

It shall be possible to replace the lamp from the canopy without opening the front glass.

8.18.8 **Outdoor Lantern Luminaires Post top Lantern**

Post top lantern luminaires shall be generally outdoor weather proof type for illumination of walkways, gate posts, gardens etc.

The luminaire shall have cast aluminium spigot of 50/60 diameter finished with corrosion proof paint for mounting, opal acrylic or high density polyethylene (HDP) diffuser bowl, complete with integral mounted control gear, neoprene gaskets, earthing terminal etc.

The luminaire shall be suitable up to 200 W incandescent lamp, 125 W mercury vapour lamps or 70 W sodium vapour lamp.

8.18.8.1 *Fluorescent Luminaires*

Street lighting fluorescent luminaire shall be outdoor weather proof type for illumination of secondary roads, walkways, peripheral lighting of buildings etc.

The luminaire shall be of semi-cut off or non-cut off type, with CRCA sheet steel housing, vitreous enamelled, plain or corrugated clear acrylic cover, complete with integral mounted control gear, neoprene gaskets, side pipe entry or top suspension type.

The luminaire shall be suitable for 1 x 40 watts or 2 x 40 watts fluorescent tubes and for mounting heights up to 4 metres.

8.18.8.2 *Mercury vapour and sodium vapour luminaires*

Street light mercury/sodium vapour luminaires shall be outdoor weather proof type for illumination of main roads, traffic islands etc.

The luminaire shall be of semi-cut off with cast aluminium housing, acrylic or prismatic cover, polished aluminium reflectors, complete with integral mounted control gear, neoprene gaskets and with rear pipe entry.

The luminaires shall be suitable up to 400 watts mercury or sodium vapour lamps and for mounting heights from 4 metres to 12 metres.

8.18.9 **Emergency Light Luminaire**

Emergency light shall be indoor type for providing emergency light during failure of normal AC supply.

- The luminaire shall be with CRCA sheet steel enclosure, complete with metallised mirror reflector, leak proof re-chargeable battery rated for two hour discharge, battery charger, charger-on lamp, push button switches, automatic changeover switch/relay, two metre length cord with plug, mounting pads and other accessories required for satisfactory operation of the luminaire.
- The luminaire shall be suitable for connection to 240 V, 50 Hz single phase supply. On failure of normal AC. supply the luminaire shall pick-up automatically and on restoration of a.c. supply the luminaire shall switch off automatically.
- The luminaire shall be suitable for incandescent lamp up to 40 W or fluorescent lamp up to 20W.

8.18.10 **Accessories for Luminaires**

8.18.10.1 *Reflectors*

- The reflectors shall be made of CRCA sheet steel/aluminium/silvered glass/chromium plated sheet copper as indicated for above mentioned luminaires.
- The thickness of steel/aluminium shall comply with relevant standards. Reflectors made of steel shall have vitreous enamelled finish. Aluminium used for reflectors shall be anodised/epoxy stove enamelled/mirror polished. The finish for the reflector shall be as indicated for above mentioned fittings.
- Reflectors shall be free from scratches or blisters and shall have a smooth and glossy surface
- Reflectors shall be readily removable from the housing for cleaning and maintenance without disturbing the lamps and without the use of tools. They shall be securely fixed to the housing by means of positive fastening device of captive type.

8.18.10.2 *Lamp/Starter Holders*

- Lamp holders shall have low contact resistance, shall be resistant to wear and shall be suitable for operation at the specified temperature without deterioration in insulation value. They shall hold the lamps in position under normal condition of shock and vibration met wit under normal installation and use. Lamp holders for the fluorescent lamps shall be of the spring loaded bi-pin rotor type. Live parts of the lamps holder shall not be exposed during insertion or removal of lamp or after the lamp has been taken out. The lamp holder contacts shall provide adequate pressure on the lamp cap pins when the lamp is in working position.
- Lamp holders for incandescent, mercury vapour and sodium vapour lamps shall be of Edison Screw (E.S.) type.
- The starter holders shall be so designed that they are mechanically robust and free from any operational difficulties. They shall be capable of withstanding the shocks met within normal transit, installation and use.

8.18.10.3 *Ballasts*

- The ballasts shall be designed to have a long service life and low power loss. The ballasts shall be of the inductive, heavy duty type copper wire wound, filled with thermosetting, insulating, moisture repellent polyester compound filled under pressure or vacuum. Ballasts shall be provided with taps to set the voltage within the range of variation in supply voltage of ±10% of 240 V. End connections and taps shall be brought out to a suitable terminal block rigidly fixed to the ballast enclosure.
- Ballasts shall be mounted using self locking, anti-vibration fixings and shall be easy to remove without demounting the fittings. They shall be in dust tight, non combustible enclosures.
- Separate ballast for each lamp shall be provided in case of multi lamp luminaires, except in the case of 2 x 20 Watts luminaires.

8.18.10.4 *Starters*

Starters shall have bi-metal electrodes and high mechanical strength. Starters shall be replaceable without disturbing the reflector or lamps and without the use of any tool. Starters shall have brass contacts and radio interference capacitors.

8.18.10.5 *Capacitors*

The capacitors shall have a constant value of capacitance and shall be connected across the supply of individual lamp circuits.

The capacitors shall be suitable for operation at specified supply voltage conditions and shall have a value of capacitance so as to correct the power factor of their corresponding lamps circuit to the extent of 0.95 phase lag or better.

The capacitors shall be hermetically sealed preferably in a metal enclosure to prevent seepage of impregnant and the ingress of moisture.

8.18.10.6 *Incandescent Lamps*

General Lighting Service (GLS) lamps shall be tungsten filament incandescent type. The filament shall be coiled coil type rated for 230/250 volts, Single phase A.C.

Lamps shall be with Edison Screw type metal lamp caps.

Lamps shall be milky white for diffused, soft, glare free lighting and rated up to 100 watts

8.18.10.7 *Fluorescent Lamps*

Fluorescent lamps shall be low pressure mercury vapour type with low wattage consumption and high efficiency and longer burning life (about 2500 hours).

Lamps shall be of white light type suitable for operation on 240 V, single phase a.c. in standard lengths of 2, 4 and 5 feet and ratings up to 65 watts.

Lamps shall be provided with features to avoid blackening of lamp ends.

8.18.10.8 *High intensity discharge lamp*

These lamps include high pressure mercury vapour lamps and high pressure sodium vapour lamps.

High pressure mercury vapour lamps shall be with quartz discharge tube, internal coated shell, quick restrike time (of within 5 minutes) and with burning life (about 5000 hours) in standard ratings up to 1000 watts.

High pressure sodium vapour lamps shall be with polycrystalline translucent, coated discharge tube, coated shell, quick restrike time (of within 5 minutes) and with burning life (about 10,000 hours) in standard ratings up to 400 watts

8.18.11 **Lighting System Equipment**

8.18.11.1 *Main Distribution Boards and Lighting Panels (AC & DC)*

Constructional Features

Boards and panels shall be sheet steel enclosed and shall be fully dust and vermin proof, providing a degree of protection of IP 54. Outdoor panels shall in addition be completely weather-proof with a sloping canopy for protection against rain and providing a degree of protection of IP 55. The sheet steel used for frame shall be cold rolled of 2.5 mm thick sand frame enclosures, doors, covers and partitions shall be cold rolled 2 mm thick.

All boards and panels shall be provided with hinged doors for access to equipment. Doors shall be gasketted all round with neoprene gaskets. For the main floor mounted distribution boards with the switch fuse units arranged in tier formation, the hinged door of each unit shall be interlocked so as to prevent opening of the door when the switch is ON and to prevent closing of the switch with the door not fully closed. However, a device for by-passing the door interlock shall be provided to enable the operation of the switch with the door open, when necessary, for examination/maintenance.

For wall mounting 1-phase ways lighting panels when provided with MCBs, a hinged, latched front door shall be provided with key-locking facility and a slotted bakelite sheet shall be provided inside.

Only the MCBs operating knobs or the fuse cap covers shall project out of the bakelite sheet slots for safe operation and neat appearance. Incomer to lighting panels shall be provided with TPN MCB with RCD

All accessible live connections/metals shall be shrouded and it shall be possible to change individual fuses, switches, MCBs from the front of the boards/panels without danger of contact with live metal.

For floor mounting type distribution boards, adequately sized mounting channels shall be supplied and for wall/column/structure mounting type panels suitable mounting straps shall be provided.

Adequate interior cabling space and suitable removable cable entry plates shall be provided for top/bottom entry of cables through glands and or conduits as required. Necessary number of glands to suit the specified cable sizes shall be provided. Cable glands shall be screwed on type and made of brass.

Two earthing terminals shall be provided.

All sheet steel parts shall undergo rust-proofing process which should include degreasing, de-scaling and a recognised phosphating process. The steel works shall then be painted with two coats of Zinc - chromate primer and two coats of final stove-enamelled finish paint of specified colour.

Busbars

Busbars shall be of aluminium of alloy grade 634 01 WP conforming to IS: 5082.

Busbars shall be provided with at least the minimum clearances in air as per applicable standards for 500 V, 3 phase system.

Busbars shall be adequately sized for the continuous current rating such that the maximum temperature of the busbars, busbar risers/droppers and contacts does not exceed 85° C under site reference temperature.

The busbars, busbar connections and busbar supports shall have sufficient strength to withstand thermal and electro-mechanical stresses of the fuse/MCB's let through/cut-off current associated with the specified short-circuit level of the system.

Busbar supports shall be made from suitable insulating material such as Hylam sheets, glass reinforced moulded plastic materials, permali wood or cast resin. Separate supports shall be provided for each phase of the busbars. If a common support is provided for all three phases, anti-tracking barriers shall be incorporated.

The neutral bus of the main 3 phase, 4 wire distribution board shall be rated not less than 50% of the phase busbars. The neutral bus of the 1 phase ways lighting panel shall be rated same as the phase busbars. The neutral bus should have sufficient terminals and detachable links for full number of single-phase outgoing lighting circuits.

Panels/Boards' Component Equipment - Switches/Miniature Circuit Breakers (MCB)

- Switches/MCBs shall be hand operated, air break, quick make, quick break type conforming to applicable standards.
- The switch shall be protected by fuse and the MCB shall be provided with overload/short-circuit protective device for protection under overload and short-circuit conditions. The minimum breaking capacity of MCBs shall be 6 kA r.m.s. at 415 V/220 V D.C.
- Switch shall have provision for locking in both fully open and closed positions. MCBs shall be provided with locking facility.
- The connections between switch and fuse shall be insulated and all live connections shall be shrouded.

Fuses

- Fuses generally shall be of the HRC cartridge fuse-link type having a certified rupturing capacity of 80 kA at 440 V. Fuses up to 63A for distribution systems of medium short circuit levels may be of HRC cartridge screw-cap, D type, having a certified rupturing capacity of not less than 46 kA at 440 V and 16 kA at 250 V D.C.
- Fuses shall be provided with visible indication to show that they have operated.
- Cartridge fuses shall preferably be mounted in moulded plastic carriers. If fuse-carriers are not provided, insulated fuse pulling handle shall be provided for each size of fuse for each switchboard.

Indicating Instruments and Meters

- Whenever required, instruments and meters shall be of the flush mounting type. They shall be suitably mounted so as to provide for easy access to CTs and small wiring.
- Instruments shall be of minimum 96 mm square size, shall have provision for zero adjustment outside the cover and black numerals on white dial.
- Watt-hour meters shall be of direct reading electro-dynamometer type complete with cyclometer type dials and reverse running stops.
- Ammeter/Voltmeter selector switches having 3 positions and off, with stay-put contacts rated 10A shall be provided when specified.
- Potential fuses shall be provided at the tap-off point from the busbars for the voltmeters.

Instrument Transformers

- Current and voltage transformers shall be of the dry type, of metering accuracy class 1.0
- Test links shall be provided in both secondary leads of the CTs to easily carry out current and phase angle measurement tests. Facilities shall be provided for short-circuiting and grounding the CTs at the terminal blocks.
- Voltage transformers shall be provided with suitably rated primary and secondary fuses.

Indicating Lamps

Indicating lamps shall be of the filament type and low watt consumption. Lamps shall be provided with series resistors.

Internal Wiring

Panels/boards shall be supplied completely wired. Wiring shall be carried out with 1100/650 V grade, PVC insulated, stranded aluminium/copper conductors. Conductors of adequate sizes shall be used to suit the rated circuit current.

- Engraved identification ferrules, marked to correspond with the wiring diagram shall be fitted at both ends of each wire.
- All wiring shall be terminated on terminal blocks. Terminal blocks shall be one piece moulded rated 500 V, of reputed make, preferably stud type for higher current ratings such that wires are connected by cable-lugs and complete with nuts and washers. Terminals shall be adequately rated for the circuit current, the minimum rating shall be 20 A.
- Terminals for circuits with voltage exceeding 125 V shall be shrouded.
- Terminals shall be numbered and provided with identification strip for identification of the circuit.
- Terminal blocks for C.T. secondary lead wires shall be provided with shorting and disconnecting/earthing facilities.

Labels & Diagram Plate

- All door mounted equipment as well as equipment mounted inside the switchboard/panels shall be provided with individual labels with equipment designation/rating. Also the boards/panels shall be provided on the front with a label engraved with the designation of the board/.
- Labels shall be made of non-rusting metal, 3-ply lamicoid or engraved PVC
- Inside the door of the 1 phase ways lighting panels a circuit diagram/description shall be fixed for refer--ence and identification.

Light Control Switches

- Light control switches of ratings and types, i.e. decorative/industrial shall be supplied as required. The switches shall be suitable for use on 240 V, 1 Ph, 50 Hz supply.

- Switches shall be of flush type for mounting behind an insulated plate or incorporated with a switch plate for mounting flush with the surface of wall or switch box/suitable enclosure. The switch box/enclosure may be recessed into or mounted on a wall as per the requirement of project layouts.
- The size of enclosure boxes shall be chosen to accommodate the number of switches to be installed at the particular location. The enclosures shall be 18 gauge sheet steel galvanised. The enclosure box shall be covered with perspex/insulating cover. An enclosure intended for surface mounting shall not have holes or gaps in its sides other than those expressly provided for cable entry.

8.18.11.2 *Feeder pillar*

Feeder Pillar shall be provided for feeding power to the street lighting system. It shall be equipped with MCB's and automatic light control switch. Street/ area lighting shall be controlled by time switch/ photocell for automatic switching of luminaries.

8.18.11.3 *Receptacle Units*

Receptacle units shall consist of socket outlet with associated switch and plug. The socket outlet and switch or MCB shall be flush mounted within galvanised 18 gauge steel enclosure with insulation cover. The box may be recessed into or mounted on a wall as per requirements of project layouts.

The receptacle units shall be suitable for 240 V, 1 ph - N, 50 Hz/415 V, 3 Ph - N, 50 Hz supply as required.

Single phase receptacles shall be associated with a switch/MCB of same current rating and the receptacle shall become live only when the associated switch/MCB is in "ON" position.

Three phase receptacles shall be associated with a TPN switch housed in the same enclosure. The receptacle shall become live only when the associated switch is in "ON" position.

The plugs shall be provided with cord grips to prevent strain and damage to conductors/wires at connection and entry points.

8.18.11.4 *Lighting Receptacle Wiring*

The wires for wiring in lighting system shall be 250/440 V, 1/C, PVC insulated, unarmoured with stranded copper conductors.

The minimum area of conductors shall be 1.5 sq.mm. for light fittings and 5A Receptacles and 4 sq.mm for receptacles rated 15 A and above.

The wires shall be coated white for phase/positive of d.c. and black for neutral/negative of d.c.

8.18.11.5 *Conduits*

Rigid steel/non-metallic conduits and their associated fittings as required shall conform to applicable standards. The minimum size of conduit shall be 20 mm for surface installation and

25 mm for concealed installation.

Steel conduits shall be seamed by welding and hot dip galvanised. They shall be supplied in standard lengths of 5 m.

Supply of conduits shall include all associated fittings like couplers, bends and tees as required for lighting system installation work.

8.18.11.6 *Junction Boxes*

Junction boxes with terminals shall be supplied for branching and terminating lighting cables when required for outdoor areas, 3 phase receptacles etc.

The junction boxes shall be dust and vermin proof and shall be fabricated from 14 gauge sheet steel and shall be complete with removable cover plate with gaskets, two earthing terminals each with nut, bolt and washer. Boxes shall be additionally weather proof.

The boxes shall have provision for wall, column, pole or structure mounting and shall be provided with cable/conduit entry knock outs, terminal blocks, HRC fuses as required.

The terminal blocks, with specified number of terminals, shall be mounted securely on brackets welded to the back sheet of the box. The terminals shall be 650 V, grade, one piece construction complete with terminals, insulation barriers, galvanised nuts, bolts and washers and provided with identification strips of PVC. The terminals shall be made of copper alloy and shall be of box clamp type.

The boxes shall be painted with one shop coat of red oxide zinc chromate primer followed by a finishing coat of paint.

8.18.11.7 *Lighting Poles and Towers*

Lighting poles for street lights and flood lights shall be of stepped tubular steel poles construction as per applicable standard. These poles shall be coated with bituminous preservative paint on the inside as well as embedded outside surface. Exposed outside surface shall be painted with one coat of red lead oxide primer. After completion of installation two coats of aluminium paint shall be applied.

The supply of poles shall be complete with fixing bracket/necessary pipe reducer for fixing the fitting and also include the necessary associated pole mounted junction boxes. The required sizes of poles and the junction box shall be as indicated in the attached drawings.

Towers for mounting flood lights shall be supplied whenever required and as per typical attached drawing. Unless otherwise specified, towers shall be painted with red lead oxide primer and two coats of aluminium paint. A steel ladder and platform at the top shall be provided. The length of each step of the ladder shall be at least 300 mm and spacing between two adjacent steps not more than 300 mm. The structure shall be suitable for mounting the required number of floodlights, weight or maintenance crew and specified wind pressure. The factor of safety shall be 2 for each part and section.

9. INSTRUMENTATION CONTROL & AUTOMATION (ICA) REQUIREMENTS

9.1 General

The Instrumentation, Control, and Automation specifications shall cater for 400 MLD (200MLD x 2 Lines) capacity Perur desalination plant. This specification defines the general requirements and philosophy for instrumentation, control and automation.

The ICA shall comprise, but not be limited to the following:

a) Plant Control System incorporating Distributed Control System (DCS) and integrated system through the internet and other protocols.
b) Plant instruments, control elements, and remote equipment;
c) Shielded data highway (including dual-redundant fiber loop) connecting all plant items;
d) Engineer and Operator workstations and a Control Desk with a Mimic and HMI Panel for Operator information;
e) All required hardware, servers, software, redundancy;
f) Local control panels, emergency stop devices, hard-wired controls, and interface terminals;
g) Alarm management system and reporting system;
h) Computer Maintenance Management System(CMMS), Conditioning Monitoring System (CMS), and Optimization system;
i) Instrumentation cabling and segregation with power supply system;
j) Secure power supplies and dual-redundant UPS system;
k) Remote communications facilities and integration;
l) Interface with external stakeholders system;
m) Redundancy and other features required to ensure SWRO Desalination Plant availability, guaranteed performance, operational control, and operational flexibility.

9.1.1 **Reference, Codes & Standards**

All the equipment's and their accessories covered in this specification shall be designed, manufactured, and tested in compliance with the latest relevant standards and codes of practices referred in the table below

STANDARDS	TITLE
INTERNATIONAL STANDARDS	
ISO	International Standardization Organization
IEC	International Electro-technical Commission
ANSI	American National Standards Institute
BSI	British Standards Institution
DIN	Deutsches Institutfür Normung
EN	European Standards

STANDARDS	TITLE
JAPS	Japanese Standard Organization
REGULATIONS, RECOMMENDATIONS, DIRECTIVES	
ACI	American Concrete Institute
AGMA	American Gear Manufacturers Association
AIJ	Architectural Institute of Japan
AISC	American Institute of Steel Construction
AISE	Association of Iron and Steel Engineers
AISI	American Iron and Steel Institute
AMCA	Air Moving and Conditioning Association
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
AWS	American Welding Society
AWWA	American Water Works Association
HIS	Hydraulic Institute Standards
IEEE	Institute of Electrical and Electronics Engineers
IPCEA	Insulated Power Cable Engineers Association
ISA	Instrument Society of America
JEC	Japanese Electro-technical Institute
JEMA	The Japan Electrical Manufacturers Association
JIS	Japanese Industrial Standards
NFPA	National Fire Protection Association
OCIMF	Oil Companies International Marine Forum
TEMA	Tubular Exchanger Manufacturers Association
IBC	International Building Code
USEPA	United States Environmental Protection Agency
VDE	Verband Deutscher Elektrotechniker (German Society of Electrical Engineers)

All equipment shall comply with the statutory requirements of the Government of India and State Government. Wherever required by regulations, the Supplier shall have to obtain approval of the Electrical Inspector / Director of Explosives / competent authority. Any changes required by the said Inspector shall be to the account of the Supplier. The same condition applies to obtain the approval of other statutory authorities. Wherever the Indian Standards do not exist, the equipment/components shall be designed, assembled, and tested under the other relevant applicable standards' latest editions.

9.1.2 Scope of Supplies and Services

a) The scope of supply shall include design, manufacture, assembly, testing at works, supply, erection, testing at site & commissioning, and handing over
b) Various Types of Field Instruments like measurement (flow, pressure, level, temperature, etc.), Transmitters, Analyzers, Sensor, etc. as required for monitoring and control of the process equipment's performance proposed in each process zone.
c) Receiving, Handling, Storing, Issuing, and Transportation to the site for installation, Erection, Testing, Commissioning, and integration with DCS of the above.
d) The Bidder shall include everything necessary for the execution of the above scope of works, whether mentioned explicitly in this document or not.
e) The Bidder shall finalize the number of instruments and their ranges during the detailed design stage.

9.2 Instrumentation

This section defines the minimum mandatory technical requirement of the instrumentation for the SWRO desalination application.

It is the responsibility of the Bidder/EPC to design the ICA that meets all criteria defined in this document as well as to achieve SWRO Desalination Plant operation, availability, guaranteed performance, operational flexibility, and durability (and service life) of the asset.

9.2.1 Instrumentation Design Considerations

a) In addition to the technical requirements of this section, the selection of technology, the design, and the arrangement of the instrumentations shall be based on the relevant Site conditions
b) The instrumentation and control equipment shall have high electromagnetic and radio frequency interference immunity and shall not be affected by portable radio transmitters operated in the equipment's vicinity.
c) Instrumentation shall be suitable in every respect for continuous operation at the maximum output as well as part loads and shall be designed to permit unconstrained operation over the full range of ambient conditions and under the anticipated transient operation conditions as well as the climatic conditions peculiar to the Site and environmental pollution restrictions.
d) The Bidder/EPC shall apply acceptable engineering practices in preparing the Instrumentation Control & Automation design. The proposed equipment shall be new and from reputable manufacturers with sufficient experience in the application's respective field.
e) The Bidder/EPC must utilize components and systems which are of new manufacture and proven design. The selection of instrumentations shall be as per internationally recognized standards and shall comply with all the applicable national and statutory codes.

f) The plant shall be designed so that the impact of a failure of any single piece auxiliary equipment will cause no reduction in the plant's output.
g) Provision for future expansion in design & selection, e.g. space inside the control room, space on the panels / cabinets / desks etc.
h) Wetted parts of the instrumentation equipment shall be selected to withstand the service fluid's physical and chemical properties coming in direct contact with the instrument.
i) Where binary signals cannot be derived from an analogue value, binary transmitters, e.g., temperature switches, pressure switches, etc. may be used. Limit switches shall be of the proximity type. All switches shall be of robust design and reliable performance and shall be of the snap-action and change over type. The switches shall have an adjustable switching hysteresis.
j) Whenever a corrosive atmosphere is present, all instruments and associated equipment exposed to such a medium shall be designed & protected to withstand the adverse effects.
k) All instruments components shall be tropicalized to protect against humidity, moisture, and fungal growth through hermetically sealed units, protective coating on circuit boards, etc.
l) All equipment shall remain unaffected by radio transmissions (Levels of permissible RFI shall be as per IEC 801).
m) The field equipment requirements are based on the usage of conventional signal interfacing by central/remote I/O equipment.
n) Generally, 2 wire transmitters shall be used. If for some particular purposes (e.g., analyzers) 230 V AC power supply is required, the output circuit shall be isolated. All transmitters shall be individually fused.
o) Necessary protections shall be taken care of for the Instruments coming in contact with a high-pressure line.
p) Colour codes for pipelines, cables, lamps, and panels shall be followed for the plant as per industry/plant standard.

9.2.2 Instrumentation Strategy

9.2.2.1 *General*

a) All field instruments shall be high standard industrial type and suitable for the coastal environmental condition.
b) All instruments, gauges, and control equipment that perform similar duties shall be of uniform type and manufacture throughout the Works to facilitate maintenance and the stocking of spare parts.
c) All instruments shall have high reliability, low power consumption, and low maintenance.
d) All materials in contact with seawater and concentrate shall be of suitable design and shall have proven suitability in the comparable installations.
e) All part of the instruments in contact with the process fluids shall be fully compatible with the fluid to be measured, process temperature, and the ambient

conditions and shall not deteriorate under normal operating conditions

f) All instruments shall be of the Latest state-of-art and proven technology

g) All instruments shall be from the reputed make with field-proven supply and service

h) All transmitters shall be SMART type. The Bidder/EPC shall consider all necessary software libraries to communicate with the supplied instrumentation via protocol

i) All transmitters shall have an accuracy of 0.5 or better, and the repeatability shall be within a range of ± 0.1% of full span.

j) All transmitters shall have local indication installed at a visible location. The transmitter and local indicator shall be integrated with the sensor were as possible. All instruments shall be mounted in visible locations with easy access for adjustments.

k) The range of local instruments shall be that the normal measurement of the process variable is between 50% and 75% of the instrument's full scale.

l) All switches shall be of robust design and reliable performance and shall be of the snap-action and change over type. The switches shall have an adjustable switching hysteresis. Limit switches shall be of the proximity type or metallic type (SPDT/DPDT).

m) All instruments installed on the Potable water line shall not affect the quality of the potable water.

n) All instruments installed on the Potable water line shall not affect the quality of the potable water.

o) All instrumentation system components, such as transmitters, analyzers, and controllers, shall be calibrated before equipment shipment. Calibration has to be documented, and testing certificates shall be included in the scope. Calibration shall be performed in five points of operating range.

p) Sunshade with UV-resistant coating shall be provided for all outdoor instruments, Control Panels, and Analyzer panels.

q) Field mounted transmitter display, indicators and gauges shall be sized to give full legibility when viewed from a position with convenient and easy access or from the point at which any operation requires observation.

r) Sampling points shall be provided for all the analytical parameters

s) All I&C equipment shall have enclosure classification not less than IP 54, according to EN 60529, when mounted in an enclosed building and IP 65 for mounting outdoors.

t) Control cubicles installed in air-conditioned rooms shall be at least IP 32.

u) Sunshades shall be provided for all cubicle located outdoor, and all cubicles shall be adequately ventilated or air-conditioned, if necessary, for operability

9.2.2.2 *Instrument Installation Philosophy*

All work shall be of the highest quality craftsmanship and shall conform to the best applicable engineering practices and relevant codes referred to in this document.

All instruments shall be installed in a neat, professional manner, ensuring ease of operation and maintenance. The EPC shall prepare hook-up and installation detail drawings regarding each instrument's type and shall carry out the installation per these approved drawings.

The EPC shall install instruments and equipment with due consideration of the following:

a) Instrument installations shall conform to all applicable standard and manufacturer specifications and warranty requirements.
b) No instrument except for pressure gauges and temperature indicators shall be installed to depend on its impulse piping or electrical connections for its support.
c) The positioning of equipment shall not constitute a safety hazard. Where possible, instruments shall be mounted so that they are protected from the effects of rain and sun while maintaining access and visibility requirements. This is not possible; the EPC shall provide a fixed cover or hood to protect instruments, without impairing access or visibility.
d) Visibility and accessibility to be provided for both maintenance and operations purposes.
e) Ease of access for lifting heavy items of equipment such as valves and flow meters.
f) All instruments and valves shall be free from vibration.
g) Instruments shall be mounted/connected so as not to stress vessel nozzles or pipe tapping.
h) All local process-connected instruments shall be located as close as possible to the measurement point while still being accessible from the deck, ladder, or platform.
i) Instruments shall be mounted at a functional level between 1.0 and 1.5 meters above the operating floor.
j) Instruments shall be appropriately supported on brackets or mounted on subplates, or placed on a suitable pedestal, pipe stand, or structural support. Pipe or structural stands may be welded directly onto the platform plate, with a proper penetration in the grating, where applicable.
k) Instruments, tubing, cables, and cable ladder shall not be fixed to gratings or handrails.
l) Instruments (other than pressure instruments) shall not be mounted directly on process piping without approval.
m) Fittings such as instrument isolating valves and instrument air or gas regulators shall be supported either on the instrument stand or close-coupled to the instrument in a manner that no undue stress is imposed o the tubing or instrument.
n) Instrument installation materials, tube, tube fittings and manifolds shall be standardized throughout the project to reduce spare supply inventories and minimize rework time for a replacement.
o) Analyzers for primary process lines shall be installed in bypass assemblies external to the main process headers to allow routine maintenance. The assemblies shall include an isolation valve at each process connection tap, pressure regulator,

manual sample valve, flow meter with integral flow metering valve, check valve, miscellaneous piping, and fittings. Assemblies for analyzer sensors, which must remain wetted at all times (e.g., pH or conductivity sensors), shall incorporate a vacuum breaker in the drain piping. The sample drain shall be routed to a hub drain.

p) Instrumentation taps to process lines shall be isolated by root valve at the point of connection. Isolation valves for taps to process lines shall be 1/4-turn ball valves of materials compatible with the process fluid. Isolation valves for chemical service shall match isolation valves used in other portions of that chemical piping.

q) Critical instrumentation associated with seawater inlet, brine discharge, Potable Water quality, or other essential parameters of process shall be duplicated and shall not use the same impulse line but have separate process tapping.

r) All field mounted transmitters vulnerable to damage shall be housed inside transmitter cabinets.

s) Wherever instrumentation equipment is installed underground, a suitable approach, sufficient space for maintenance, drainage, ventilation, and illumination shall be provided.

t) All cables laid below surface level or in trenches are to be installed in PVC conduits, and these conduits are to be sealed to prevent the ingress of moisture or water even if submerged.

u) Cables carrying electricity and cables carrying digital communications must be laid in separate conduits to prevent electromagnetic interference.

v) Plugging of extra holes in JB's, panels, cabinets, etc., plugging of additional holes for conduits, filling up the conduits & conduit opening with waterproof sealing compound after completion of erection.

9.2.2.3 *Instrumentation Redundancy Strategy*

a) Instrumentation shall be designed such that the impact of a failure of any single piece of instrument and auxiliaries will cause no reduction in the output of the plant.

b) Redundancy shall be applied such that "No" single I&C failure shall:
   - Cause any danger to personnel and the plant;
   - Invalidate protection by inhibiting a trip;
   - Shut down more than one Major Equipment item;
   - Simultaneously trip a Plant item and invalidate its auto-change-over; and
   - Affect more than one control area.

c) Instrument Voting:
   - If a parameter envisaged to trip a part of the plant process and eventually reduce the production, then the instrument voting of that parameter the shall be 2oo2
   - If a parameter envisaged tripping the entire plant and complete loss of production, then the instrument voting of that parameter shall be derived

from 2oo3

The Bidder/EPC may propose feasible solutions as per their control strategy, considering point b above.

d) Measuring points and measuring equipment for interlocking and protection purposes for the critical control points shall be separate and not combined with measuring equipment for monitoring or automatic control equipment, except they are designed in a redundant configuration (2oo2 or 2oo3 voting).

9.2.3 **Field Instrumentation**

A general guideline on the Selection and approach of the instrumentation is given below. However, the selection of a particular type of sensor shall be decided based on the application requirement.

9.2.3.1 *Pressure Measurement*

a) All pressure instruments shall be provided with the isolation valve and vent/drain valve or manifold.
b) The differential pressure transmitter/indicator shall be mounted with a manifold.
c) Transmitter housing shall be made of Die-cast aluminum, with a minimum IP rating of IP65.
d) All wetted parts shall be made of Hastelloy C or AISI 316 depending upon the process fluid to be measured.
e) Pressure transmitters and gauges shall have over-range protection up to 1.5 times the maximum line pressure they may be exposed to.
f) Where necessary, a special diaphragm shall be used to segregate the gauge tube from corrosive fluid media. Minimum it shall be used in sludge and chemical dosages.
g) Pressure transmitters shall have accuracy typically better than 0.25% of span.
h) For pressure measurement in slurries, viscous and corrosive fluids, diaphragm seals of suitable material shall be provided along with pressure sensing devices.
i) Pressure gauges shall have minimum dial size of 100 mm.
j) Pressure gauges shall have a threaded process connection of ½" NPT male.
k) Pressure gauges shall be in general bourdon type, white with black markings dials for 270 degrees of the dial. The pointer shall be externally adjustable, and the gauge movements shall be stainless steel, geared type. The case shall have a blowout disc in the back. Ranges are typically selected such that the operating point falls between 1/3 and 2/3 of the full-scale range. Indicators are located such that they are visible from the floor or adjacent platforms, where practical.
l) The window material of the pressure gauge shall be shatterproof glass.
m) Pressure gauges/switches used in pulsating pressure applications (e.g., the delivery side of pumps, compressors, etc.) shall be provided with externally adjustable pulsation dampener or snubber.
n) Wherever the process pressure exceeds 30 bar, solid front type pressure gauges shall be used (i.e., a metal partition shall be provided between dial and element).

o) The sealing liquid for the diaphragm seal shall be an inert liquid compatible with process fluid and its temperature.
p) Pressure gauges shall have an external zero adjustment facility.

9.2.3.2 *Flow Measurement – Electro Magnetic Flowmeter*

a) Flow transducers shall be rugged in construction and shall be suitable for continuous operation. Flow transducers shall have waterproof construction and shall be suitable for installation in underground/above ground applications.
b) To avoid the effects of disturbances in the velocity profile, a straight and uninterrupted run, upstream and downstream from the flow sensor's location, shall be provided in accordance with the requirements of the flow meter manufacturer.
c) Flow Meter shall be of the electromagnetic flow-through type with a minimum accuracy of 0.2 % at flows between 15 - 110 % concerning the nominal flow.
d) Potable water metering flowmeter shall have an accuracy of 0.1% at flows between 15 - 110 % to the nominal flow.
e) Flow sensing element and liner shall be fully compatible with the fluid to be measured, process temperature, and the ambient conditions and shall not deteriorate under normal operating conditions
f) Flow meters shall be designed to operate on 230 VAC power supply, and a 10% variation in power line voltage shall not affect the meter output accuracy over 0.1 % of the full scale
g) The remote mounted transmitter is preferred, and it shall be located for easy access.
h) The transmitter shall be a smart type with outputs including 4-20mA (HART), Pulse, and programmable relay discrete output. The transmitter shall include flow rate, alarm monitoring, self-diagnostics, and forward/reverse/net flow totalizer.
i) The measuring electrode, the reference electrode, and the empty pipe detection electrode shall be inbuilt, and the type of electrodes shall be manufacturer specifics based on the process fluid.
j) Flowmeter shall be provided with inbuilt grounding electrodes, and the material shall be the same as the sensing material. Insulation flanges, gasket, and copper shall be provided as required.
k) Flowmeter flanges shall be in accordance with ANSI / ASME.
l) If the pipework has cathodic protection, the manufacturer's recommendations for bonding and protecting the instrument and its signals shall be adhered to.
m) Rotameters
    - Rotameters shall be provided for areas where the flow parameters are only for monitoring and the least priority. Simple manufacturer standard scaled tube and float shall be used for line sizes less than 100mm, and for higher size pipes with the exception that the process pressure is not disturbed, a bypass type flow rotameter arrangement with flow restriction orifice plate shall be used. The rotameters shall be provided with discrete SPDT switches.
    - Rotameter shall be a metal tube/glass type as applicable for process fluids; material shall be selected according to process requirements and fluids.

9.2.3.3 *Level measurement*

a) The level measurement system shall consist of a level transducer, level transmitter, digital level indicator, and any other items required to complete the level measuring system
b) Level instruments shall have weatherproof, dust, and corrosion-resistant enclosures of IP-67 grade.
c) Level instrument materials of construction shall be compatible with the fluids to be measure and the service conditions.
d) Level probes, waveguides, and stilling wells shall be situated to allow sufficient overhead clearance for their installation and removal.
e) Flushing ring, drain valves, tubings shall be provided where required.
f) Accuracy of the level measurements shall be better than ± 0.5% of full scale or 10mm
g) The design and application of level meters shall consider the vessel or channel construction, the material, size, shape, environment, process fluid or material, the presence of foam, granules, size, etc.
h) The transmitters shall be 4-20mA (24V DC loop powered) / Field bus compatible and possible to calibrate through handheld universal and field bus configurators.
i) Ultrasonic Level Measurement
   - Ultrasonic type level transmitters shall be microprocessor-based and shall use digital signal processing techniques for signal conditioning.
   - The transmitter shall have facilities for storing the echo profile, manipulating the echo profile to remove noise, multiple profile-averaging, etc.
   - The transmitter shall have the capability to use statistical filtering techniques, wherever required, to compensate for rotating agitator blades or to suppress false signals due to heavy dust or fill-stream interference.
   - In applications where material build-up on the sensor is expected, the transducer shall have suitable build-up compensation (i.e., repetitive, pulsating displacement at its face shall be used to remove the material build-up).

9.2.3.4 *Analyzer*

a) All analyzers shall be industrial type, proven design, robust construction, low maintenance, and suitable for the intended application.
b) Each process area shall be provided with the required type of analyzer to monitor the process condition.
c) The different types of analyzers required in plants are pH, ORP, Turbidity, Temperature, Conductivity, Free Chlorine, Oil, Hydrocarbons, SDI, Alkalinity, .etc.
d) The type of sensors and measuring principle shall be selected based on the liquid's electrochemical and physical properties.
e) The analyzers shall be selected based on reagentless or reagent free operation

f) Multi-parameter type analyzers shall be used, but transmitter output shall be individual and dedicated per each parameter.
g) Analyzers shall be installed in analyzer panels if a cluster of analytical equipment exists in an area. Analyzer panels shall be installed, preferably in a sheltered area; when a circumstance requires the outdoor installation, the suitable shelter shall be provided to protect from direct sunlight and rain.
h) The analyzer panel shall be made of Plastic UV resistant panel or vendor standard material to withstand the climatic condition.
i) Suitable drain arrangement shall be provided where required.
j) Analyzer cabinet with air-conditioner shall be provided for analyzer were required based on manufacturer recommendation.
k) The analyzer cabinet shall be made of GRP or FRP with a minimum degree of protection of IP67.
l) pH:
   - The measuring electrode shall be glass with a suitable reference electrode (preferably silver).
   - Measurement shall be flow-through type, and the Sensor element shall have a built-in temperature sensor for temperature compensation. The electrode response shall be linear with temperature changes.
   - The systems shall have an auto cleaning facility and facility of auto-calibration.
m) ORP
   - The measuring electrode shall be platinum/gold with a suitable reference electrode (preferably silver)
   - pH and ORP sensors can be connected to a single transmitter, in which case the transmitter shall be capable of processing the two input signals as per the requirement
n) Conductivity
   - In the case of flow-through, the electrode shall be preferably titanium/ SS316L with a suitable reference electrode
o) Turbidity
   - Turbidity measurement shall be based on the Nephelometric measuring principle 90° NIR scattered light according to ISO 7027/ EN 27027
   - It shall be complete with the light source, light receivers, sensor assembly with an integrated viper, flow assembly with integrated gas bubble trap, Remote transmitter, etc.
   - An internal bubble removal system shall be included to vent entrained air from the sample stream.
p) TOC
   - TOC measurement shall be based on Non-Dispersive Infrared TN1/2012/04 Sensing Technology
   - The analyzer shall measure organics reliably in high-salt or brine samples with a precision of +/-2% with a range of 0-250ppm and calibration

stability of min. 6 months.

q) SDI
- Online SDI measurement shall be automatic for continuous monitoring &unattended operation in the desalination plant.
- Facility for data logging, status display, fault detection, auto flushing/cleaning, control of water pressure, flow rate measurement, automatic transfer of filters after each measurement, number of measurement (as required), etc.

r) Oil
- The probe shall be a continuous-reading sensor that utilizes a UV-fluorescence technology.
- The sensor shall be equipped with a stain-resistant measuring window. The sensor shall compensate for the interference effects of ambient light and UV lamp output fluctuations.

9.2.4 Condition Monitoring System (CMS)

a) The Integrated Machine Condition Monitoring system is required for all the critical Pumps; the criticality of the pumps shall be based on
- The impact of the failure of a pump and auxiliaries will cause no reduction in the plant's output.
- The failure of the pump doesn't affect more than one process area.
- Size of the pump

b) The critical pumps are listed below, but not limited to the following
- Sea Water Intake Pumps
- RO Feedwater Pumps
- High-Pressure Pumps
- Booster Pumps

The Bidder/EPC, with their experience, shall include additional pumps, which may be sought as critical.

c) It is recommended that the sensors for the condition monitoring system shall be supplied by the respective pump vendor dully installed and wired to their respective cabinet.

d) Various parameters such as Vibration, axial displacement, thrust, temperature, speed, key phasor, etc. shall be measured and made available for analysis and interlocking

e) The data gathered from various machines shall be used for monitoring, machine diagnostic analysis, and decision support. The vendor shall provide software capable of data monitoring functionality in client-server configuration so that monitoring, diagnostics analysis, and configuration changes are possible from CMS Workstation.

f) The CMS shall be modular and expandable

g) The CMS server shall have provision for interfacing Process data from the DCS in the respective control room for correlation of Fault diagnostics. The same shall be available from the OPC server's Ethernet port in the control room being provided by the DCS vendor. The vendor's scope shall include coordination with the DCS vendor, including identifying process data required, developing the OPC client module at their end (CMS server), and successful integration with DCS.

h) Condition Monitoring system server shall have OPC connectivity with DCS network and shall comply with OPC foundation standards. A firewall shall be provided for the MCMS servers by the DCS vendor for the interface.

i) Fault diagnostic analysis software shall be able to detect various malfunctions like shift bow, high synchronous vibration, fluid-induced instabilities, radial preloads forces, shaft crack, rotor rub, loose rotating parts, electric motor non-uniform, air gap, etc

j) Software shall have the capability to evaluate the following data for analysis, as a minimum:
    - Magnitude and amplitude of the vibration
    - Form of vibration
    - Amplitude/Phase lag angle
    - Shaft centerline position
    - Frequency of the vibration
    - Process variable data
    - Machine geometry data
    - Trend file data
    - Report history files

k) The following list of parameters are to be included as a minimum but not limited to:
    - Vibration monitoring
    - Temperature monitoring

   The final quantity of monitoring parameters to be installed in each type of equipment is confirmed by each equipment manufacturer's specific vendor and according to the mechanical construction.

l) Vibration monitoring shall measure bearing vibrations by accepting any voltage output or standard electric piezoelectric accelerometer. A minimum of two vibration transducers shall be provided for each bearing when permitted by the equipment's mechanical design.

m) Temperature monitoring shall be intended for the measurement of winding and bearing temperatures. Each equipment shall be provided for motor winding temperature monitoring points, motor bearing temperature monitoring points, and Pump bearing temperature monitoring points.

n) The Bidder/EPC shall be responsible for coordinating with various Machine vendors (Original Equipment Manufacturers) concerning:
    - Obtaining/validation of required information for the engineering of offered CMS.
    - Verification of configuration data during Installation and commissioning.

- Calibration verification of sensors and monitors during commissioning.

9.3 Distributed Control System (DCS)

Due to the requirement of availability, reliability, and function, the Plant processes' control and monitoring task be performed by a state of art digital Distributed Control System unified for all SWRO units and other main plant equipment. The DCS shall be of proven design successfully in operation at other similar desalination plants.

The Bidder/EPC/Vendor shall be responsible for designing the integrated DCS, based on the information given in this specification, its referenced requirements and standards, and accompanying drawings/documents.

The listed requirements presented here in this section are intended as minimum recommendations and provide general guidelines and establish minimum system requirements.

9.3.1 DCS Strategy

a) A tentative DCS architecture for the SWRO Desalination Plant is attached within the drawing section ref: 7061563/PMC400MLD/CP1/DCS/001.The DCS shall incorporate Distributed controllers, Plant Control Station, Various Operator Workstations, engineering workstations, Control Servers, Controllers, Historian, Optimisation/CMMS server, and touch screen displays for field control & annunciation.
Remote input/output (I/O) racks shall be distributed throughout the site to minimize the amount of wiring back to the central control room. The SWRO Desalination Plant shall be visible from the Control room.

b) The Design strategy for the DCS shall take into consideration the following criteria:
   - Fail-Safe Design
   - System Availability
   - Equipment Reliability
   - Expandability
   - User friendly to operate and maintain
   - Fault Monitoring and Diagnostic Capability
   - Compatibility for Integration with the third party

c) The DCS shall synchronize the date and time via the GPS clock provided. All DCS facilities shall be synchronized to this system time and date, which shall be used to tag all alarm and events and in all displays and reports.

d) The SWRO Desalination Plant shall use a tree-type communications system to integrate equipment, instruments, and computers. The equipment level systems shall communicate with motor control centers, variable frequency drives, and other PLC's using standard Plant control network protocols.
The instrument-level system (field bus) shall communicate to most of the process instruments, air-operated valves, and/or motor operated valves using field bus,

hardwired or equivalent.
The computers shall communicate peer to peer via standard TCP/IP or equivalent Ethernet.

9.3.2 Redundant Configuration

a) Process and Mechanical redundancy should be reflected in the DCS redundancy as well. The plant is envisaged into two independent production lines configuration of 2 x 200MLD, and the DCS redundancy should be harmonized as per the envisaged Process and Mechanical redundancy.

b) The following equipment shall be supplied in a redundant configuration
   - All Controllers.
   - All Power supply modules.
   - All Control network equipment.
   - All communications equipment required for communications between controllers, Servers, and Workstations
   - All applicable station level equipment's

c) The following requirements apply to those parts of the system supplied in a redundant or fault-tolerant configuration:
   - The system shall continuously monitor and test all backup equipment to determine whether the backup equipment can assume control.
   - Failure of backup Equipment shall be alarmed as a system alarm.
   - Automatic switchover to backup equipment shall occur on the detection of failure of the primary equipment.
   - Switchover shall not degrade the module's performance or functionality or result in the operator's loss of view to the process.
   - Switchover of controllers shall not cause the initialization of any control strategies implemented in the controllers.
   - Replacement of any redundant module shall not disturb or interfere with the redundant pair's functional module's performance.
   - Switch back to repaired equipment shall be permitted only after the system diagnostics function has determined that the module is fully functional.
   - Automatic and manual switchover shall be displayed, logged, and alarmed by the system.

d) The following requirements apply to the Control Network and Internal Communications
   - DCS networks shall be based upon industry standards from IEEE/IEC.
   - Communication at the control network level shall have redundant or fault-tolerant paths.
   - Communications from the controller to the I/O subsystem shall have redundant paths.
   - DCS internal communication shall be designed such that no single failure will degrade the performance of the system. This requirement applies to all

communication between controllers to their I/O modules.

- Data highways shall continuously use both paths and shall check the backup path at least once per minute to determine if the backup path is operating normally.

9.3.3 Availability

a) A single failure anywhere in the system shall not result in the loss of production and regulatory control.

b) A single failure anywhere in the system shall not result in the loss of an operator's ability to view or manipulate the process from his workstation.

9.3.4 Reliability

Equipment supplied as part of the DCS system shall meet or exceed the MTBF data specified below at the equipment's design temperature.

- Process controllers and input/output modules – 300,000 hrs
- Power Supply modules – 200,000 hrs
- Commercial off-the-shelf networking or communications equipment – 100,000 hrs
- All other electronic modules and power supply modules – 100,000 hrs

MTBF figures shall be "Predicted" using data and calculation provided by MIL-HDBK-217.

9.3.5 System Support

DCS Bidder/EPC/Vendor shall guarantee support of all hardware, firmware, and software associated with the controller and I/O subsystems and any proprietary communications equipment for ten (10) years from the hardware freeze date. Support shall include spare parts and technical support.

9.3.6 Scope of Supply and services

The scope of supply and services includes (but not limited to) for Distributed Control System (DCS) / Controller shall include designing, engineering, manufacturing, software development, testing, erection, commissioning, documentation, and handing over complete plant control system to ensure satisfactory operation of the plant. Including Complete Integrated Plant Control System for Data Acquisition, Data Processing, Process Monitoring, Process Control, Process optimization, Events and alarm handling, Data storage, retrieval and analysis, Diagnostics, and Information exchange with Management / Office network. The design shall be in accordance with Bidder/EPC/Vendor standards but with amendments to meet the CMWSSB/Engineer specifications.

9.3.7 DCS Hardware Requirement

9.3.7.1 *Scope of Supply and Services DCS Hardware*

The scope of supply and service for DCS hardware includes, but not limited to:

a) Distributed Control System (DCS) /Controller, PC based HMI units; Control desks; servers and redundant servers; computers for operator stations, plant overview, process optimization, information management system, peripherals; programmable controllers (PCs); power supplies; ethernet switches; distributed / remote I/O panels along with Large Screens, Monitors for plant overview shall be Min. 55" LED type shall be provided.

b) Modems / protocol converters / data transmission RF transmitters / receivers / link devices / Ethernet switches / coupler / terminators / routers / bridges / power supplies for communication wherever required, as per system configuration.

c) Ergonomic furniture for operators & Engineers at Main Plant Central Control Room (CCR)

d) The laptop computer of the latest configuration with necessary licensed software loaded as Portable Programming Unit for the programmable controller and other field instruments/devices/drives.

9.3.7.2 *Distributed Process Controllers*

a) The controllers shall be of a minimum 32 bit, high performance, RISC, multi-task processing. Including adequate clock frequency capability to process in 16 bits

b) The CPU load shall not be more than 60%. The memory utilisation shall be within 60%, the loading of communication channels like high-speed Ethernet, I/O channels, and programming terminal channel, if any, shall be less than 60%.

c) The controllers shall be programmed to achieve sequential interlocks for a start/stop of plant and machinery, process and safety interlocks, alarm generation & distribution, monitoring and supervision of process parameters and PI / PID, fuzzy loop controls for process optimization.

d) Controllers shall be controlling the sections independently & the stoppage of one controller shall not affect the operation of others unless otherwise they are deliberately interlocked. However, these processors shall also communicate between themselves to take care of the safety interlocks/process requirements shared between the process related sections. Any programmable controller in the network can access the data and I/O of any other controller in the same network.

e) The processors shall have self-diagnostic features to ensure healthy working at all times, including memory, processor loading, the status of communication channels, and to give warning through audio-visual means for any fault in the same. Suitable programming devices to facilitate online program changes; storage of program for safekeeping and handheld terminal shall be included.

f) Process controllers shall be redundant, with automatic failover to the backup processor on the primary processor's failure. Engineering of a redundant unit should be transparent, i.e., no extra manual synchronization shall be needed. The backup processor shall be in hot standby mode, continuously updating its memory from the primary controller. The redundancy should have a switch over time less than 10 msec.

g) Controllers shall be supplied in a configuration to ensure continuous and bumpless processing of data while permitting online changes to control logic. There shall be an online and offline programming feature. The programmable controller shall have Remote, run, program, online program & test modes (Simulation mode).

h) The system shall have scalability both horizontally and vertically. The details of scalability in terms of number & type of controllers, number & type of I/O, number & type of communication modules, number of MMI, number of external systems, number & type of network nodes, different communication protocols, software, size of memory, additional functionality, distance, the mix of multiple processors, networks & I/O without restrictions, etc. are to be furnished by the Bidder.

9.3.7.3 *Inputs And Outputs*

a) I/Os in Panels or integrated to MCC shall be connected to DCS Controller through a redundant serial link.

b) The I/O and their interfaces shall have provisions configured either as remote I/O or as distributed I/O. The protocol envisaged for this purpose shall be of industry standard and open protocol. The same shall be mentioned in the Bid.

c) As far as possible, field bus devices/transmitters shall be used. If such devices/transmitters are not available for any application, they shall be with a 4–20 mA DC analog signal with HART communication.

d) I/O panels required to be mounted at the field away from MCC rooms etc. shall have IP65 protection.

e) Input / Output (I/O) modules shall be capable of being inserted into or removed from their chassis or mounting assemblies without disturbing field wiring and while the chassis is powered (hot replacement).

f) All Input / Output modules shall provide a status LED that indicates the module's health or operational condition. The status of the module shall also be communicated to the system diagnostics software.

g) The modules selected shall be of rugged construction, low power consumption/heat dissipation, and to an extent, do not require forced cooling.

9.3.7.4 *Analog Input*

a) The system shall automatically check the calibration of the A/D converters periodically.

b) The system shall indicate calibration error.

c) The noise level generated by the input circuitry shall be less than the minimum resolution of the measurement.

d) Analog input modules shall power 4-20 mA field instrumentation loops with a loop resistance of 600 ohms.

e) Analog input modules shall be able to connect to 4 wire field instruments.

9.3.7.5 *Discrete Input*

a) The system shall be capable of detecting discrete input transitions with a duration of 50 milliseconds.
b) 24Vdc inputs shall be able to use either internal or external power supplies. External power supplies may provide other voltages.
c) Relay or solid-state input from field powered contacts shall be available.
d) The system shall support configurable digital input filtering to prevent digital input "chatter" or "bounce."
e) Discrete input modules shall have visible LED indicators on a per-channel basis to indicate the input's current state.

9.3.7.6 *Analog Output*

a) The system shall support 4-20 mA outputs.
b) Output modules shall be provided with individually fused outputs or current limiters.
c) Analog output modules shall have the following configurable failsafe options:
d) Drive to zero output or full-scale output
e) Maintain last good output value

9.3.7.7 *Discrete Output*

a) The system shall be capable of supporting the following:
    - On/off
    - Single pulse, (configurable width).
    - Latching and non-latching (momentary) contact outputs
b) The following solid state or relay board output ratings shall be available:
    - 24 VDC, 80 mA, non-inductive load
c) Relay or solid-state output contacts that are free of voltage and ground shall be available.
d) The duration of the single pulse outputs shall be individually configurable.
e) Output modules shall be provided with individually fused outputs or current limiters.
f) Discrete output circuits shall be provided with protection for the switching of inductive loads.
g) Discrete output modules shall have visible LED indicators on a per-channel basis to indicate the output's current state.
h) Discrete output modules shall have the following configurable fail-safe options:
    - Drive to either energize or de-energize output
    - Hold last output

9.3.8 DCS Software Requirement

a) The online real-time operating system supplied shall be proven for similar applications and shall support all the equipment/peripherals.

b) For Level -1, a Licensed software bundle for online & offline programming, configuring, diagnosis, troubleshooting, firmware update of flash PROMs of the controllers along with necessary drivers and interfaces shall be included and specified by the Bidder

c) For Level- 2, Licensed Operator Station software / Human Machine Interface (HMI) software for graphics development, tag configuration & management, data acquisition, plant viewing, plant operation, plant control, real-time & historian trending, alarm generation, and log reporting, event log, historian, PID, and other process loop manual & auto-tuning, interfacing & access for Field Bus devices/drives, interfacing & access for Management Information System (MIS) & Process Optimization Systems, OPC interface shall be included and specified by the Bidder.

d) Any other software required for the reliable & successful operation of the desalination plant and the system offered

e) The DCS system shall carry out the following functions on data received from the plant facilities:

- Perform control algorithms as per configuration
- Store historical information
- Produce logs, reports, and trends
- Handle alarms and events
- Calculate derived values
- Run application programs like measurement validation and comparison, valve stroke testing
- Perform logic control and sequencing
- Trending and Reports generation
- Auto window generation of trending and Grouping from the tags in each Graphic display using soft key
- Safe view (Multi-window opening with the facility to open the window in the specified position with the first opened – first closing principle)
- HMI availability embedded in the FCS for viewing Advanced diagnostic and predictive maintenance feature (Latest version) for valves and transmitters
- Grouping of alarms UNIT / Equipment-wise
- Forcing I/O signals to individual states via the engineering workstation for commissioning and maintenance purposes.
- Loading I/O cards and Grouping of logics.
- Perform configuration of all HART devices from a single engineering station
- Automatically perform diagnostic checks on all conventional HART

devices and continuously report their status and health to the operator interface.

- Provide the necessary software interface to the third-party devices

f) The Bidder/EPC/Vendor shall supply:
   - Fully configured database(s)
   - Fully configured overview, operating, alarm and trend displays sufficient to provide full control and monitoring as specified by the CMWSSB/Engineer
   - Fully integrated single database for process control and asset management data
   - Fully configured tabular display pages
   - Fully configured mimic displays
   - Fully configured reports as specified by the CMWSSB/Engineer
   - All other software required to meet the Specifications
   - All User-Defined Programs supplied under this Contract
   - Offline Diagnostic Software for comprehensive testing of the DCS

g) The Bidder/EPC/Vendor shall ensure that all hardware and software supplied are mutually compatible and function through interfaces with any other equipment or software.

h) Control Functions:

   The following standard control algorithms shall, as a minimum, be available for configuration:

   - Normal PID
   - Cascaded Loops
   - High/Low Over-Ride Selection
   - Ratio Algorithms
   - Feed Forward Control
   - PID with Gap Action
   - Summer / Subtractor
   - Multiplier / Divider
   - Boolean Operations
   - Differential Gap Control
   - SetPoint Tracking (remote / local)
   - External Reset Feedback (EFB)

9.3.8.1 *Optimization Package*

a) An optimization/expert system, along with necessary hardware & software, shall be provided. This optimization package shall be an integral part of the automation system or a standalone system.

b) The system shall be designed so that even if the expert optimization system fails, the plant operation shall not get affected, and all the controls shall automatically get transferred to appropriate control levels.

c) The optimization system shall provide a solution for the advanced process of membranes in desalination plant with the following minimum functions:
   - Monitors the membrane fouling through Key Performance Indices (KPIs)
   - Estimates the due date for next membrane chemical cleaning
   - Provides the optimal set points to improve the productivity / minimize energy consumption
   - Maximize membrane life and reduces unplanned outages
   - Maximizes water production and decreases operating cost

9.3.8.2 *Historian Package*

a) Online History Collection and Storage
   There shall be a configurable, real-time, and historical data collection package to support trending, logging, and reporting.
b) Offline History Storage
   It shall be possible to archive raw historical data for long term data storage. The facility to recall and display any data that has been archived shall be provided. The system shall keep a record of data that is transferred to removable media. The record shall contain the timeframe of the data transferred and the name of the file or storage area to which it has been transferred.

9.3.8.3 *Computerized Maintenance Management System (CMMS)*

A completely integrated computerized Maintenance Management System(CMMS) with relevant databases entirely populated and customized for desalination plant application shall be provided. The system to be provided shall include all necessary hardware, software, firmware, and interfaces required for implementing a fully functional CMMS suitable for integrated maintenance management function for a modern SWRO Desalination.

9.3.8.4 *Database*

It is required that the DCS maintains, on mass storage media, the complete current database. Any changes made to the database shall also be copied to this backup. If a memory loss occurs, then the DCS shall reload with either an archived or the current backup version of the database from the storage.

9.3.9 **DCS Controller Grouping**

a) DCS controller and RIO shall be grouped. The Bidder/EPC/Vendor shall specify an indicative number of IOs. The requirement and scheme of remote IOs shall be established.
b) The vendor shall ensure DCS IO loading is within limits.
c) Grouping of the controller shall be such that inter controller communication for acquisition and interlock are minimized to its extent.

9.3.10 Control Room

a) The complete desalination plant operations shall be operated and monitored from four operator stations located in Central Control Room
b) The control desk and the associated furniture shall be ergonomically designed as per standard industrial practices for comfortable working to the operators. The furniture shall comply with the relevant IEC standard for ergonomic design.
c) Colour Monitors, Keyboards, mouse, printers, Public Address System Master Unit, Walkie Talkie Station, P&T telephone, intercom telephone, CCTV switching unit, Process Log Books, etc. Shall be mounted/placed on Control Desk inappropriate cutouts / suitable arrangements.

9.3.11 Local HMI

Local HMI shall be provided for the controllers. Local HMI shall be provided at each area control station, which can be used sparingly in case of urgency only. This HMI shall be hooked directly to the controller liable to control functions of the concerned area.

9.3.12 Communication

a) DCS networks shall be based upon industry standards from IEEE/IEC.
b) High-Speed Ethernet communication shall be used for monitoring and control of the plant. There shall be two networks, such as Plant Bus and Station Bus.
c) Plant Bus shall have all Controllers, Application Server, Historian Server, OPC server, and Engineering Station connected to it. Station Bus shall have Operator stations, printer, and GPS clock connected to it.
d) Ring-type Network Topology shall be followed.
e) A firewall shall be provided for interfacing the Station bus with other LAN and interfacing outside network.
f) Level 0 shall contain all field instruments, Profibus DP slave devices such as VSD, Package Vendor PLC's, MOV, Control valve, and electrical switchgear feeders.
g) Level 1 shall contain all controllers and communication with field devices.
h) Level 2 shall be having both plant and station bus. This level shall contain all controllers, application server, operator stations, engineering station, Historian server, and GPS clock
i) Level 3 & Leve 4 shall be an interface to external systems using TCP/IP or Internet
j) Communication network-level shall be redundant or fault-tolerant paths.
k) Communications from the controller to the I/O subsystem shall have redundant paths.
l) Communication shall be designed such that no single failure will degrade the performance of the system. This requirement applies to all communication between controllers to their I/O modules.
m) Open system Interconnection type data highway shall be provided

n) Communication speed shall be Min. 100 MB/ sec.
o) Topology: Bus topology with (two) redundant network having Manageable Ethernet switches. The Bidder shall also ensure that 25% of spare parts are available in ethernet switches.

9.3.13 Alarms and Message Handling

Alarm Management and Optimisation shall be envisaged as per standards during the abnormal and crisis condition.

9.3.14 Displays and Graphics

a) All displays and graphics that show real-time data shall update automatically when the collection is resident on the screen. Updates shall not require operator initiation.
b) Special indication shall be used to indicate that a value is invalid.
c) The update frequency for real-time data displayed alphanumerically and symbolically (shape change, color change, etc.) shall be at least once every two (2) seconds for all displays and graphics.

9.3.15 Diagnostics

9.3.15.1 *General*

a) The status of all modules shall be periodically checked to verify the online status and operation.
b) Errors shall be alarmed with an error message identifying the effected module.
c) The status of each online module shall be checked at least once per minute.
d) Diagnostic tools shall provide the following information:
e) Module status (e.g., online, offline, failed, standby)
f) Overall Processor loading (CPU) for controllers and other vendor proprietary DCS modules exclusive of I/O Modules.
g) Network utilization of control network.
h) Software and firmware (if applicable) version of all modules installed in the system.
i) System and Diagnostic Displays

9.3.15.2 *Communication System Status Displays*

Standard displays shall show as minimum as the operational status of the communication system. Each module's state connected to the communication system (online, offline, failed, primarily failed, backup failed) shall be shown.

9.3.15.3 *Module Status Displays*

Displays shall be provided to show the operational status and error conditions for all system modules down to the card level.

9.3.15.4 *Diagnostics*

a) Online and offline diagnostics shall be provided to assist in system maintenance and troubleshooting. Diagnostics shall be provided for every major system component and peripheral. If diagnostics do not exist for a particular peripheral device (for example, printers and terminals), the system must detect and provide an error indication for these devices' failure.
b) Online displays shall indicate the results of self-diagnostic tests. Failure diagnosis shall be sufficiently specific to indicate which printed circuit boards, modules, or devices are at fault. The displays shall be designed to help maintenance and engineering personnel diagnose faults in the system and communications paths. Each category of diagnostic display shall be organised hierarchically.
c) Communications diagnostic displays shall show errors for each of the redundant paths.

9.3.16 **DCS Electrical Requirements**

9.3.16.1 *Power Supply and Distribution*

a) Equipment shall be powered from separate Uninterruptible Power Supply (UPS).

9.3.16.2 *Redundancy*

a) All controllers, I/O modules, communication networks, and I/O bus communications equipment shall be fed from redundant UPS power sources.
b) A single failure of any power supply shall not fail more than one module in a pair of redundant DCS modules. This failure shall not cause a disturbance to the process or result in loss of operator functionality.
c) Power supplies shall be capable of being removed and replaced without disturbing the other power supplies' operation.
d) Power supplies for the same voltage rating shall be of the same make and model for interchangeability and spare parts management.
e) The power supply to a controller, I/O, or communications module is supplied from the chassis or baseplate, which houses the module. The chassis or baseplate shall be fed from two separate power supply circuits. Each circuit shall be provided from different and independent power sources.
f) Power supply redundancy shall be provided using either an N+N configuration.

9.3.16.3 *Power Distribution within DCS Cabinets*

a) Power supplies that feed multiple chassis or base plates shall have their outputs wired to a power distribution panel within the cabinet. The term "power distribution panel" in the above requirement and subsequent requirements of this section refers to a collection of din-rail mounted circuit breakers and/or fused terminal blocks, terminal blocks, and wiring used to distribute power to multiple loads from a single source.
b) Branch circuits from power supplies shall be individually fused or protected by a circuit breaker.

c) Terminal blocks in the power distribution panel shall be segregated by voltage level.
d) Power distribution terminal block wiring shall not be daisy-chained using wires or crimp connectors. Jumper bars or preformed jumper combs designed for the specific terminal blocks being used are acceptable methods of distributing power supply wiring.

9.3.16.4 *Revision Level*

a) All controller and I/O subsystem hardware and other vendors proprietary hardware shall be the latest "field-proven" revision level
b) All vendor proprietary software, exclusive of application software, shall be the most recent, commercially released, software revision level
c) All personal computers, monitors, printers, peripherals, Ethernet switches, and other commercial off-the-shelf (COTS) equipment provided by the vendor as part of the system shall be the latest model available
d) The system shall allow for upgrading of system operating Software on all redundant modules of the system without requiring a shutdown of any process equipment, without losing the operator's view to the process, and without the loss of access to any control function.

9.3.17 **Documents to be submitted during Bid Submission**

a) A filled-in table of Conformance to every part of the specifications. Use a chart format with the specification part identified, indicate whether each element complies, a deviation, or an exception to the specific part. If any exception or deviation, include a narrative description of how the deviation or exception can benefit the end-user.
b) Provide a written overview of the proposed DCS system, instrumentation system describing the principal functions and capabilities of the system's PC, controllers, system communications, and general system capabilities (maximum number of network nodes, Controllers and I/O points, communication protocols available, etc.).
c) Provide an equipment list with descriptive literature for the proposed system. Included on the list shall be all major hardware items. The list shall consist of a minimum, the manufacturer, and model numbers. Technical schedules for Instruments, Controllers & DCS shall be duly filled with relevant details.
d) Provide an operating system and software applications list with descriptive literature for the proposed system. Include all significant software items, supplier name, quantity, and model numbers. Indicate whether any proposed software is proprietary and would not be turned over to the owner.

9.4 Interfaces – External Systems

9.4.1 CP2 – Pumping Station towards CMWSSB

a) To link the CP1 Desal plant data to CMWSSB control centre, a new interface panel shall be located at the CP2 pumping station, which shall be connected to CP1 desal plant DCS through the FOC link. All analogue and digital signals, as requested by CMWSSB, shall be made available in this interface panel. CP2 bidder shall take the CP1 signals from the interface panel towards CMWSSB control centre.
b) All equipment (e.g., fibre optic cables, patch panel, patch cords, fibre optic converter, cabinet, etc.) for the interface cubicle required for the connection between CP1 DCS and CP2 pumping station interface panel shall be provided.
c) CMWSSB SCADA system shall be interfaced with DCS using Modbus TCP/IP for real-time operation

9.4.2 TANGEDCO / TNEB

a) The interface point to the TANGEDCO/TNEB shall be the interface cubicle for analogue/ binary signal exchange located at the central power supply receiving station. This interface panel shall be supplied, and installation is as part of the CP1 project scope.
b) All required equipment (e.g., fibre optic cables, patch panel, patch cords, fibre optic converter, cabinet, etc.) shall be provided.
c) All signal sharing between the TNADGEDCO SCADA and DCS shall be interfaced through this cubicle. The list of signals is to be finalized during the detailed design stage.
d) The communication protocol between DCS and TANGEDCO/TNEB shall be decided during the detailed design stage.

9.4.3 TN Pollution Control Board / TNCRZ / CMWSSB

a) The User-specific information shall be made available to the stakeholders TNPCB, TNCRZ, and CMWSSB.
b) The Webserver shall populate the required information based on user rights.
c) The list of data for sharing shall be decided during the detailed design stage.

9.5 Cyber Security

9.5.1 Codes & Standards

Material or equipment supplied to this specification shall comply with the latest edition of the references listed below unless otherwise noted

STANDARDS	TITLE
IEC 62443-3-3	Industrial communication networks – Network and system security

STANDARDS	TITLE
ISO 9001	Quality Management Systems – requirements.
IEC 61000-6-2	Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments
ISA 99	Industrial Automation and Controls Systems Security
ISA-62443-3-3	Security for industrial automation and control systems Part 3-3: System security requirements and security levels

9.5.2 Network Architecture

Ref the tentative DCS System Architecture drawing: 7061563/PMC400MLD/CP1/DCS/001

a) Level 1 and Level 2 networks shall use physically separate network switches and routers from Level 3 & 4 networks.
b) IT Components on Level 1 and 2 shall be separated from Level 3 and above by a managed firewall. The firewall policies or rules should be configured such that only required communications are possible.
c) Level 3 and above systems shall be configured using firewall policies or rules that permit only required traffic. All policies or rules applied to the firewalls not required during the operate phase shall be removed before the handover is run and maintained.
d) Internet access from IT Components directly connected to Level 1, or Level 0 shall not be allowed, and Internet access from other IT Components shall be:
    - Via the process control access domain proxy and
    - From and to explicitly authorized systems and
    - Specify a fully qualified domain name for the internet host, and
    - Route traffic through the process control access domain firewall.

e) All unused interface ports (e.g., Ethernet and USB) on IT Components shall be protected against unauthorized access. This includes, but is not limited to, configuration and diagnostic ports or interfaces. This requirement intentionally leaves it to the project to decide on the means of protection, e.g., logical or physical.
f) Remote user access and remote management access to L4, L3, and L2 network devices shall only be permitted via the firewall.
g) Access to L1 network devices and below shall be limited to Internal Remote Access.
h) All IT Components requiring antivirus or patch updates shall be network-connected where technically possible, thus allowing centrally located services to provide these updates. This allows for centralized management and monitoring of

IT Components.

9.5.3 Firewall

All firewalls implemented shall be state-full inspection hardware firewalls. The firewall rules shall be configured to deny all traffic except for the traffic, which is required explicitly for the system.

Firewalls shall be subject to a rule set review at least annually, to ensure that only the necessary traffic is permitted.

9.5.4 Access Control

a) All network traffic between Level-2 and any other domain SHALL be through a secure firewall solution unless an IP connection is impossible. If and where non-IP modems are used to access a Level-2 IT Component, the following shall apply:
   - The modem shall be physically disconnected or disabled when not in use, and
   - A documented procedure for monitoring remote user activities when the modem is in use shall be applied. This procedure shall be reviewed and approved by the IT Security Accountable Manager.

b) If in case external remote user access to Level-2 applications and IT Components is required, this shall be authenticated with the following minimum criteria:
   - Two-factor authentication, or
   - One-time password.

c) External remote user access accounts shall be locked after six consecutive failed authentication login attempts.

d) The Level-2 shall provide the capability of restricting and terminating any external remote user access session:
   - Manually by the administrator, or
   - Automatically by specifying an allowed session time, and upon exceeding the specified session time

e) IT Components at Level 2 requiring system-to-system access to the Internet via the proxy service shall be isolated in one or more dedicated VLAN(s). The firewall policy of the firewall protecting the Level 2 network shall be configured to allow outgoing only connections from the Level 2 IT Component IP address to the proxy IP address.

f) Each IT Component in the network shall have a documented procedure for applying system hardening techniques from the Supplier, the original manufacturer (e.g., Microsoft™), or the Center for Internet Security (CIS) or NIST. The procedure shall include Supplier endorsement.

g) Before commissioning, all IT Component elements that are not required during the operate phase shall be removed; at a minimum, the following shall be reviewed and removed if not needed:
   - User accounts and groups

- Applications, utilities, services

9.5.5 **User Groups and User Roles**

a) The system shall be capable of defining user groups or user roles. System access privileges shall be configurable for each user group or user role. Individual user privileges shall be determined based on the user group/role to which they are assigned.

b) The system shall be capable of defining the following user roles as a minimum:
   - View Only
   - Plant Operator (1 – 10 plant operator roles shall be specifiable)
   - Process Supervisor
   - Engineer
   - System administrator

9.5.6 **Operating System Security Patches**

a) Patches shall be approved (qualified) by the system Supplier before installation.

b) There shall be a procedure for the installation of qualified emergency patches

c) An exposure level shall be determined for each IT Component in scope to apply operating system security patches. Per the applicable component, one of the following exposure levels shall be determined and stored in the asset inventory:

Low	Qualified patches will be applied at least once every 12 months during the operating phase.
Medium	Qualified patches will be applied at least once every 6 months during the operating phase. At a minimum, this includes systems designed to use portable media and/or network file transfer during their normal course of operation.
High	Qualified patches will be applied at least once every 3 months during the operating phase.

9.5.7 **Event Log Management**

The log files shall, at a minimum, include the following information:

a) For Microsoft™ Windows®-based IT Components:
   - Account login failures.
   - Discovery of an infected file.
   - Shutdown and restart.
   - Change to the event logging configuration.
   - Account password change and reset.
   - Account, group, and OU addition, deletion, or group membership change.

- Microsoft™ Windows® group policy modifications.
- Successful system administrator and operator logons shall be logged.

b) For other IT Components (i.e., Unix systems, switches, routers, and firewalls):
- Account login failures.
- Discovery of an infected file.
- Shutdown and restart.
- Unauthorized devices.
- Change to the event logging configuration
- Account password change and reset.
- Account addition, deletion, or group membership change.
- Configuration changes.
- Successful system administrator and operator logons shall be logged

9.5.8 **Antivirus**

a) IT Components supporting antivirus software shall be checked for computer viruses before being installed into or connected to the network.
b) Antivirus software shall be configured to automatically scan files accessed by the IT component and configured to log and notify malware-infected files.
c) The impact of a full antivirus scan on the operational performance of the component shall be evaluated when determining the frequency for performing the full scan and use of automated or manual full scans on the IT Component

9.5.9 **System Hardening**

a) Removal or non-installation of software and functionality that is not required for the system's intended functional purpose; e.g., E-mail, office applications, games, USB ports, Bluetooth, and Wi-Fi communication, etc.
b) Physical and logical access to diagnostic and configuration ports shall be protected.
c) All unused ports on switches and routers shall be disabled to prevent unauthorized access to the network infrastructure.
d) The Supplier shall demonstrate the use of hardening guidelines, tools, and instructions from either the original manufacturer (e.g., Microsoft®) and/or reputable organizations (e.g., NSA security configuration guides, NIST).

9.5.10 **Backup, Restore, and Disaster Recovery**

a) The system shall be backed-up at [user defined] intervals that fulfill the data restore and disaster recovery objectives for the system.
b) A backup shall be completed before an engineering change being made to the hardware or software, e.g.:
- Installing an operating system patch or upgrade
- Hardware modifications
- Before a change is made for which automatic roll-back is impossible

- After modifications to the system (scheduling changes, authorization and authentication changes, process trip, or application changes).

c) The following types of data shall be backed-up:
- Operating system files
- Applications (including middleware, such as an OPC tunneller)
- Configuration data
- Database files
- Log files
- Electronic logbook
- Unconventional file types; e.g., network equipment settings, DCS controller settings (tuning parameters, set points, alarm levels, etc.), field instrumentation parameters, and Microsoft® Active Directory
- Other files, identified by the Supplier, are required to create a complete backup of the Supplier's system.

d) The vendor shall provide detailed instructions on making a full backup of its system using at least one of the four methods below.
- Proprietary backup architecture on removable media
- Single system backup architecture on removable media
- Distributed backup architecture
- Centralized backup architecture

9.5.11 **Remote Access**

Where there is a requirement for remote support of DCS systems, secure connectivity solutions shall be implemented to ensure that:

- Communications outside of the electronic security perimeter are encrypted;
- User accounts authenticate users with passwords which conform at least with the baseline password standard;
- User privileges are restricted to only those required to fulfill remote support roles.
- Connectivity for remote access shall only be available when required and authorized, i.e., remote access connectivity shall not permanently be in place.

9.6 Spares

9.6.1 **Equipment Spares**

a) After Commissioning of the system, at least 20% installed spare capacity shall be provided for each type of I/O module, and 20% spare software tags shall be provided in DCS

b) At least 20% of spare terminals, PDB circuit breakers, and cable trunking shall be provided.

c) Within each system cabinet, at least 20% spare card/module positions shall be available for future modifications within the racks.
d) The software (application) spare capacity for the communication connections to third party devices shall be at least 20%
e) Loading on the control processors shall not exceed 60 % of its capacity
f) Future spare space shall be 10%

9.6.2 Spare Parts

a) The Bidder/EPC/Vendor shall provide any special tools, spare parts required for permanent installation at the site as part of the supply.
b) These shall include all non-standard equipment needed to perform installation and maintenance. All special tools are to be supplied in the sectionalised purpose-built cases with hinged lids.
c) The vendor shall indicate the list of recommended tools, spare parts, etc. to be maintained by the SSCC during the operational period.
d) The vendor shall supply all spare parts & consumables required for installation and commissioning operation based on vendor recommendation.
e) Spare parts and consumables for two years of commercial operation after commissioning operation.

9.7 Operation Control & Monitoring Strategy

The following Operation, Monitoring, and Control strategy section set forth the essential specific requirement for safe operation and control of the SWRO desalination Plant. The listed requirements presented here in this section are intended as minimum recommendations and provide general guidelines and establish minimum system requirements.

It is the responsibility of the Bidder/EPC to design each system that meets all criteria defined in this document as well as to achieve SWRO Desalination Plant operation, availability, guaranteed performance, operational flexibility, and durability (and service life) of the asset. In close collaboration with CWSSB and PMC.

9.7.1 Seawater Intake System

9.7.1.1 *System Description*

Seawater enters the plant through the intake pumping station. The intake system consists of:

a) Intake pump station: with pumps equipped with VFDs, regulating the flow of raw water according to water demand delivers the raw seawater to the pre-treatment system.
b) Screens: Mechanical screening equipment consisting of rotating band screens (mesh ≤ 5mm) provided upstream of the intake pumps for screening debris and marine organisms. Spray jets arrangement shall be provided to clean the band

screen.

c) Sodium hypochlorite Dosing: To prevent the growth of marine organisms in the intake structure
d) Airbust system: Jellyfish prevention system

9.7.1.2 *Instrumentation*

a) Instrumentations are to be envisaged as per the instrumentation requirements referred to in section 9.2.
b) As a minimum following instrumentation is to be provided, but not limited to:
   i) Total Hydrocarbons, at intake forebay
   ii) Turbidity, at intake forebay
   iii) Total Organic Carbon (TOC), at intake forebay
   iv) Algal Content Expressed as Algae Concentration of Chlorophyll, at intake forebay
   v) pH, at intake forebay
   vi) Chlorine, at intake forebay
   vii) Parameters listed in the Seawater Intake Quality specifications
   viii) Level for intake chamber, intake forebay, and Pump bay
   ix) Flow and Pressure for Pump discharge
   x) Protection and Condition monitoring for the pumps
   xi) Any other device required to meet the operations, guarantee, and environment
c) Instrumentations to ensure the raw seawater is within the design envelope and to provide sufficient information to adjust the Pre-treatment process
d) Instrumentation shall be sufficient to operate and follow over the project life of the pumps and associated equipment
e) Any other instruments to achieve SWRO Desalination Plant operation, availability, guaranteed performance, operational flexibility, and durability (and service life) of the asset.

9.7.1.3 *Automation Control Strategy*

a) Intake Pump Flow: The intake pump station shall be demand driven by the RO requirement and maintain the RO feed water tank level. During the plant's initial startup, the intake pump station level control loop shall control the RO feed water tank level maintaining at 95%. Once the RO trains are functioning, the seawater pumping station control loop shall switch to a cascaded control loop maintaining the RO flow demand and the RO feed water tank level.
b) Combined control system control loop programming and the VFDs tuning shall consider operating the pumps at its best efficiency point. If the intake flow is suspended for any reason, including non-routine, this shall trigger an automatic intake pump shutdown sequence.
c) Intake Pump Flushing: Flushing with service water shall be incorporated during the pump stopping sequence to avoid long time contact of seawater with the idle pump.

d) Intake pumps Screens Cleaning: There will be a consistent spray of water to clean the traveling screen. In case manual cleaning is needed, the screens cleaning sequence will be controlled based on level difference or based on the timer for scrapping and cleaning.
e) Chlorine Shock dosing: Timer or intermittent dosing shall be envisaged for the intake pipeline as per the Operator decision, the dosing system to maintain the dosing > 12ppm. Simultaneously a flow controlled dosing to be envisaged for the intake forebay.
f) The flowrate on the seawater supply pumps' discharge shall regulate the coagulant, flocculants, and acid dosing rates towards the Pre-treatment system.

9.7.1.4 *Key Operational Monitoring Points*

a) Following seawater parameter shall be continuously monitored, appropriate alarms should be raised with high priority:
    - Low Intake Well Water Level at intake forebay
    - High TOC, at intake forebay
    - High TDS (Conductivity), at intake forebay
    - High Turbidity, at intake forebay
    - High Temperature, at intake forebay
    - High pH, at intake forebay
    - High Algae, at intake forebay
    - High Chlorine, at intake forebay
    - High/Low Flow, Pressure & Level, for pumps & intake forebay
    - Loss of REMOTE status and Measurements from connected devices
b) Pump Condition Monitoring: The condition monitoring system alarms are set as per the Original Equipment Manufacturer (OEM) limits. All warnings are to be configured as high priority alarms.
c) Dry run protection: The pumps shall be protected from running dry by appropriate hardwired and software interlocks. The level measurement readings are to be considered the early warning and proper actions to be taken by the operator.
d) Other monitoring and safeguarding strategies align with the instrumentation design criteria philosophy referred to in section 9.2.2.

9.7.1.5 *Critical Control Point, CCP-1:*

a) Seawater Intake, Oil and Hydrocarbon CCP-1
   The intake pump control system shall incorporate provisions to alarm at the high seawater quality parameters' level above the acceptable limits. Provision shall be there to automatically shut the pumps and the intake structure(Gates) automatically connected to the seawater supply line; if seawater Oil and Hydrocarbons are excessively high beyond the limit. Appropriate instrument voting should be provided for the instrumentation reading the parameter.
b) Instrument voting on (2oo2) shall be provided, thus avoiding damage to the downstream plant.

c) The automatic closure or shutting must not result in transients that cause damage to any of the infrastructure.

9.7.2 Pre-Treatment System

9.7.2.1 *System Description*

The Pre-treatment system aims at transforming the raw seawater into feedwater for the RO membranes. Pre-treatment facilities shall be provided ahead of the RO system to protect the integrity and consistent performance of the downstream cartridge filters and reverse osmosis membrane system. The pre-treatment system will:

- Remove suspended and settleable colloids and particles.
- Achieve a pre-treatment product water quality

9.7.2.2 *Instrumentation & Monitoring:*

a) Instrumentations are to be envisaged as per the instrumentation requirements referred to in section 9.2.
b) As a minimum following instrumentation is to be provided but not limited to:
   i) Chlorine Residual, before Cartridge filters
   ii) pH, before Cartridge filters
   iii) Conductivity, before Cartridge filters
   iv) Temperature, before Cartridge filters
   v) Boron, before Cartridge filters
   vi) Pressure and Flow measurements for all associated pumps and discharge lines
   vii) Protection and Condition monitoring for the pumps
   viii) Any other device required to meet the operations, guarantee, and environment
c) Instrumentations to ensure RO feed Water meets the quality and quantity for the RO process.
d) Any other instruments to achieve SWRO Desalination Plant operation, availability, guaranteed performance, operational flexibility, and durability (and service life) of the asset.
e) All pumps of Backwash Pumps, Scour Blowers, Filtrate Pumps, Maturation pumps, and other equipment shall be monitored. All ancillary equipment should be arranged on duty/standby and provided with a VSD to ensure efficient operation.
f) Instrumentation shall be sufficient to operate and follow over the project life of the associated equipment

9.7.2.3 *Process Strategy*

The Pre-Treatment system installed on the plant shall be equipped with Coagulation, Flocculation chambers, Lamella Filters, DAF, and DMF.

a) Flash Mixing

The coagulant dosing provides a positive charge in the form of metallic cations that destabilize the particles' natural negative charge. The metallic cations combine with hydroxide in the water to form a metallic hydroxide that is an insoluble compound. The destabilized particles and metal hydroxide precipitate after agglomerating into small visible particles called flocs.

b) Flocculation Chamber

The flocculation reagent added to the seawater eases the formation of floccules. A complete line for its preparation and dosage has been included. This reagent is added to the seawater before the flocculation chambers (with low-speed mixing).

c) Lamella Filters

Lamella filters are to be designed and supplied by OEM; Lamella filters shall be designed to remove 90-95% of the suspended solids from the raw seawater. The collected turbid materials shall be drained from the filter to the wastewater tank periodically. The effluent from the lamella filters flows into the DAF.

d) DAF

Dissolved Air Floatation (DAF) system shall be operated to reduce the light TSS particle in seawater. The DAF system shall be instrumental if the algal blooms' occurrence prevents the desalination plant operating at the design availability of 98% and/or complying with the water quality requirements of the pre-treatment system.

The DAF uses microbubbles that cause the coagulated and flocculated particles to float onto the clarification basin's surface. If the raw seawater condition concerning Turbidity and algal measurement is within range and not very bad, recycling and micro bubbling processes will be held in standby mode. In this operational mode, the seawater will pass the DAF without treatment.

The operator will determine the micro bubbling floatation operation according to the conditions of the raw seawater and requirements in the downstream DMF.

e) GDMF

Effluent from DAF flows into DMF, which contains anthracite and Silica in each Bed. Adequate size and Layer thickness to be specified by the Bidder/EPC. When gravity filters are chosen following objectives are to be considered as a minimum:

- Low energy consumption
- Capacity to deal with essential loads of suspended solids and other contaminants
- To deal with fast variations
- The quality of the obtained filtered water is steady
- Very low or none, chemical product needs

The backwashing system shall be provided with all pumping setup and scenario to maintain the GDMF performance. Maturation pumps shall be provided to recycle the bed rinse water back to the filter inlet channel.

f) RO FEED Water and Backwash Tank

After the gravity filtration stage, the filtered water is collected into an inline tank with two compartments first one compartment for backwash overflowing to the

second compartment to ensure the backwash reserve is always maintained full.
Filtered water is forwarded to the RO system's inlet, through the cartridge filters, utilizing RO Feed pumps. Two types of RO feed pump (HPBP to HPP) with discharge pressure to satisfy HP NPSHr conditions and (ERDBP to ERD) with minimum pressure to feed ERD to pressure the brine to the outfall tank.

9.7.2.4 *Automation Control Strategy*

a) GDMF Backwash
Gravity Media Filters are to be back washed automatically. Filtered water stored in the filtrate storage tank shall be used for filter backwash.
The following shall be the minimum procedural steps in Backwashing; the Bidder/EPC shall optimize the Backwash step and timing as per performance requirement:
    - Drain step
    - Air scouring step
    - Venting step
    - Backwashing step
    - Rinsing step

Backwashing programming shall be triggered by controlling the water level inside the gravity filters, the difference of flow between the filter inlet and output, and the Turbidity of the filtered water. It shall be possible to determine the necessity of cleaning the filter beds. Alternatively, a Timer based on 24hr countdown shall be used as an option once a filter is sequenced into filtration mode.

b) RO Feed Water Pumps
The flow rate from the RO feed transfer pumps' discharge shall be controlled automatically by the pressure and flow control of the RO demand.

c) Sea Water Intake Dosing
The flow controller on the seawater supply pumps' discharge shall automatically regulate the coagulant, flocculants, and acid dosing rates towards the Pre-treatment system proportion to the feed flow rate.

d) Pre-Treatment Chemical Dosing
Several dosages of chemical reagents are present in the Pre-treatment System. These dosages' objective is to prepare water characteristics to those required by physical pre-treatments and RO stages. The following sections include a description of this part of dosing:
    - Coagulant Dosing
      Flash mixing is done in the Coagulation chamber after injection, coagulant and polymer are mixed with a mixer impeller running at 40-100 RPM, and contact time about 20 seconds.
    - Flocculant Dosing
      Slow mixing is done in the Flocculation Chamber with slow mixing impeller running at 3-6RPM and contact time about 20min.

e) All chemical feed dosing rates shall be tuned, optimized, and sent via the plant control system.

f) A presentation of the dosing points are included in the CCP drawing 7061563/PMC/400MLD/CP1/PFD/001, and final dosing points are to be optimized by the EPC.

9.7.2.5 *Key Operational Monitoring Points*

a) Level transmitter installed in the RO Feedwater tank shall be used to prevent the RO feed transfer pumps and GDMF backwash pumps from starting if the tank level is low, high priority alarms are to be configured.
b) Following filtered water parameter shall be continuously monitored before pumping towards Cartridge filter, appropriate alarms should be raised with high priority:
    - High Turbidity, before Cartridge filters
    - High pH, before Cartridge filters
    - High Boron, before Cartridge filters
    - High Residual Chlorine, before Cartridge filters
    - High / Low; Flow, Pressure, and Level, for associated pumps and tanks
    - Loss of REMOTE status and Measurements from connected devices
c) Pump Condition Monitoring: The condition monitoring system alarms are to be set as per the OEM limits. All warnings are to be configured as high priority alarms.
d) Dry run protection: The pumps shall be protected from running dry by appropriate hardwired and software interlocks, the readings from the level measurement to be considered as the early warning and appropriate actions to be taken by the operator
e) Other monitoring and safeguarding strategies are in line with the instrumentation design criteria philosophy referred to in Section 9.2.2.

9.7.3 **Reverse Osmosis System**

9.7.3.1 *System Description*

The RO system envelopes the following:

- RO Feedwater Conditioning.
- RO Membrane Trains.
- Membrane Cleaning System.
- Membrane Flushing System.

9.7.3.2 *Instrumentation & Monitoring:*

a) Instrumentations are to be envisaged as per the instrumentation requirements referred to in section 9.2.
b) As a minimum following instrumentation is to be provided but not limited to:
    i) Instrumentation and Controls to Protect the Integrity and Life of the RO Membranes
    ii) ORP(Redox), after cartridge filters
    iii) Turbidity, after cartridge filters

iv) pH, after cartridge filters
v) Conductivity, after cartridge filters
vi) Temperature, after cartridge filters
vii) Differential Pressure Measurement
viii) Pressure and Flow measurements
ix) Protection and Condition monitoring for the pumps
x) Any other device required to meet the operations, guarantee, and environment

c) Any other instruments to achieve SWRO Desalination Plant operation, availability, guaranteed performance, operational flexibility, and durability (and service life) of the asset.
d) RO instrumentation shall be sufficient to implement the membrane follow up (as per membrane supplier recommendation), in particular, NSP (Normalised Salt Passage), NDP (Normalised Differential pressure), NPF (Normalised Permeate flow)
e) An instrument station equipped with Residual Chlorine, Redox, Conductivity, Turbidity, and pH instruments shall be installed to monitor quality before the reverse osmosis membranes.
f) The cartridge filters shall be equipped with a differential pressure meter with high differential pressure alarm.
g) HP Pumps, Booster Pumps, RO Feed pumps, CIP pumps, and Flushing pumps shall be monitored. All ancillary equipment should be arranged on duty/standby and provided with a VSD to ensure efficient operation.
h) Necessary instrumentations to follow over the project life on the performance of membranes, to trigger CIP operation (and follow CIP efficiency), and to trigger membrane replacement

9.7.3.3 *Process Strzategy*

a) RO Feedwater Conditioning
Pumped filtered RO feed water to the RO system shall be conditioned to remove residual oxidants, prevent scale formation of the membrane elements, and provide a final barrier against incidental particulate breakthrough from the pre-treatment system.
Anti scalant shall be injected into the low-pressure feed stream to prevent sparingly soluble salts' precipitation in the RO concentrate stream. Scale inhibitors (antiscalants) shall be used to control mainly carbonate, sulfate, and calcium fluoride scaling. Preparation and dosing systems have to be considered.
The feedwater must be de-chlorinated to prevent oxidation of the RO membranes. The feed water to the SWRO system shall be treated with sodium bisulfite when the oxidation-reduction potential in RO feed water exceeds 250 mV. Similarly, an online Boron Analyzer shall be provided in the RO feed pump discharge to measure the Boron content and appropriately dose NaOH. Chemical preparation and dosing systems for Sodium bisulfite and NaOH to be considered.
The retention of the final particulate barrier in the pre-treated water shall be

achieved through cartridge filtration sized ≤ 5 µm. These filters' function is to protect the RO HPP and RO membranes from contamination introduced after the pre-treatment system and/or failure or breakthrough through the membrane filters/granular media filters.

b) RO Membrane Train

RO Membrane Train is a stand-alone modular unit incorporating a high-pressure feed pump, pressure vessels with membrane elements installed on racks, vessel manifold piping, permeate header, and concentrate header flow control, booster pump, ERD, associated instrumentation, and valves. The train shall be operated manually from the local control panel and control system.

c) Membrane Cleaning System

Membrane Cleaning System is a permanently piped clean-in-place (CIP) system to clean membranes in each RO train in-situ. Cleaning solutions shall be prepared in a cleaning solution storage tank(s) and pumped through the train vessels being cleaned via dedicated solution feed and return pipe headers.

Membrane Cleaning system the capacity of the installed cleaning solution storage tank(s) shall be sufficient to clean all vessels from a single batch of prepared solution. In addition to the cleaning solution feed and return connections on the feed/concentrate manifolds of each train, individually isolated return connections shall be provided on each train's permeate header to recycle permeate created during cleaning back to the cleaning solution storage tank(s). The system shall be designed to mix and recirculate a range of other cleaning chemicals made up of RO permeate

d) Membrane Flushing System

Membrane Flushing system is a permanently piped membrane flushing system that automatically flushes vessels of the RO trains along with the high-pressure pump within 30 minutes of a shutdown to remove residual concentrate or as stipulated in the RO membrane warranty. The Flushing shall be accomplished using the RO system permeate, which does not contain post-treatment chemicals. The flushing shall be done simultaneously for the RO pumps and membranes.

9.7.3.4 *Automation Control Strategy*

a) RO Membrane Train

Each train shall be fed, discharge, and controlled independently from the other trains, and each train shall be capable of being started and stopped from the control system interface terminal(s). Configurable operating parameters shall include the train permeate flow setpoint and recovery set point.

Automated control sequences shall be developed to start up individual trains, monitor train performance during operation, shut down trains (under both emergency and non-emergency conditions), and flush trains. The control system shall be configured to allow operators to select individual trains for operation; or input an overall system setpoint, designate trains available for operation, and enable the control system to determine trains for operation.

The system shall receive status feedback from all controlled devices (e.g., ON, REMOTE, OPEN, CLOSED, etc.) to confirm that all devices are in the correct operating mode and that requested control actions are successfully implemented. System operation shall require all associated devices in the REMOTE or AUTO operating modes before system start or continued operation.

Train permeate flow shall be controlled by varying the high-pressure feed pump's speed to achieve the selected permeate flow set point. Train recovery shall be regulated by controlling concentrate flow to a set point derived from permeate and recovery set points through modulation of the energy recovery system or train concentrate control valve (as applicable). Additional automated flow valves shall be provided for each train as follows but not limited to:

- Feedwater inlet valve on the suction side of the high-pressure feed pump.
- Flush inlet valve on the suction side of the high-pressure feed pump.
- Permeate isolation valve, on the train permeate header.
- Permeate dump valve, on the train permeate header (configured to fail open on loss of power).

b) Membrane Cleaning System

The membrane cleaning system shall be initiated manually by the operator, located near the cleaning tank(s) and recirculation pump. The panel shall house system indicators and alarm lamps and controls for the pump and tank immersion heaters. All instrumentation indicators (including gauges) shall be mounted on the panel or the panel support frame assembly.

c) Membrane Flushing System

Train flushing shall be controlled automatically through the control system to flush individual trains on shutdown. The system shall be configured to allow manual initiation of train flushes and stop a flush in progress. If multiple trains require a flush simultaneously, the control system shall be configured to flush them one at a time in sequence.

d) RO Feed Water Conditioning Chemical Dosing

All chemical feed dosing rates shall be tuned, optimized, and sent via the plant control system. The dosing points presentation is in the CCP drawing 7061563/PMC/400MLD/CP1/PFD/001 final dosing points are to be optimized by the EPC.

The proposed dosages, type, and locations of water conditioning chemicals shall not contradict the RO system membrane manufacturer's standards, as documented on the RO membrane supplier guarantee. System design shall incorporate the listed facilities and any additional facilities required to guarantee compliance with the acceptance criteria.

9.7.3.5 *Key Operational Monitoring Points*

a) Based on the measured parameters, the following configurable alarms shall be provided as a minimum for the continued operation of the train, alarms should be configured as a high priority, and associated interlocks should be programmed accordingly:

- High Differential Pressure across Cartridge Filters
- High feed water pressure.
- The high differential pressure across the individual bank of pressure vessels.
- High permeate flow.
- Low permeate flow.
- Low concentrate flow.
- High permeate pressure.
- High permeate conductivity.
- Loss of REMOTE status and Measurements from connected devices

b) Pump Condition Monitoring: The condition monitoring system alarms are to be set as per the OEM limits. All warnings are to be configured as high priority alarms.

c) Dry run protection: The pumps shall be protected from running dry by appropriate hardwired and software interlocks. The level measurement readings are considered the early warning and proper actions to be taken by the operator.

d) Other monitoring and safeguarding strategies align with the instrumentation design criteria philosophy referred to in section 9.2.2.

9.7.3.6 *Critical Control Point – CCP 2:*

a) RO Feed Water Oxidizing Agents CCP-2a
The control system shall incorporate the provisions to automatically shut the running RO trains when high oxidizing agents are detected in the RO feed filtered water after the dose of SMBS. Th
The maximum allowable value and duration of exposure should be chosen based on warrantees by the membrane supplier/vendor.

b) Instrument voting on ORP (2oo3) shall be provided, thus avoiding damage to the RO membranes.

c) RO Feed Water Boron measurement, CCP-2b
Boron analyzer shall be installed in the main RO feedwater pump discharge. When the online Boron measurement is high, the control system shall incorporate the provisions to alarm in the beginning and allow NaOH's controlled dose before the RO system to reduce the Boron in permeate within the permissible limit. The shutting of the trains shall be strategically planned based on the combination of parameter readings.

d) The trip or shutting down of the RO system in an adverse situation must not result in transients that damage any other systems or infrastructure.

9.7.3.7 *Critical Control Point – CCP 3*

a) Permeate Water TDS/Conductivity and Flow, CCP-3

The control system shall incorporate the provisions to alarm in the beginning and later automatically shut the running RO train where the high TDS detected in the permeate water. The maximum allowable value should be chosen based on warrantees by the membrane supplier/vendor. After early warnings are included in the Key Operational Monitoring points, the shutting down the RO train should be programmed based on a timer or by operator decision. The same philosophy shall be implemented for the permeate flow parameter.

9.7.4 **Post-Treatment**

9.7.4.1 *System Description*

Post-treatment system to include two key components

- Remineralization
- Disinfection

The objective of remineralization is to achieve sufficient Hardness and Alkalinity in the product water while maintaining acceptable Turbidity according to the Indian standard, IS 10500 (2012), that shall be <1 NTU.

The objective of disinfection is to ensure protection during transportation in the product distribution line. Chlorine, in the form of sodium hypochlorite (NaOCl), shall be used as a disinfection chemical for biological growth control.

Permeate from the SWRO system shall be conditioned with a combination of lime and carbon dioxide and disinfected with NaOCl to ensure safe and non-corrosive water supply. The final pH adjustment, if needed, shall be done by NaOH doing after disinfection to keep the LSI (Langelier Saturation Index) within the acceptable limit to avoid corrosion in the transmission pipeline.

The post-treatment system shall be designed such that the water exiting the Product water tank meets the drinking water quality requirements.

9.7.4.2 *Instrumentation & Monitoring:*

a) Instrumentations are to be envisaged as per the instrumentation requirements referred to in section 9.2.
b) As a minimum following instrumentation is to be provided but not limited to:
   - i) Hardness, after limestone filter
   - ii) Chlorine Residual, after limestone filter
   - iii) Turbidity, after limestone filter
   - iv) pH, after limestone filter
   - v) Conductivity, after limestone filter
   - vi) Boron, after limestone filter
   - vii) Level, at limestone silo
   - viii) Pressure and Flow measurements
   - ix) Calcite Bed Blanket level Measurement
   - x) Any other device required to meet the operations, guarantee, and

environment

c) Instrumentations shall ensure for the online parameters that product water meets contractual requirements in quality and quantity.
d) Any other instruments to achieve the Water Quality, SWRO Desalination Plant operation, availability, guaranteed performance, operational flexibility, and durability (and service life) of the asset.
e) Necessary instrumentation shall be sufficient to operate and follow over the project life of the pumps and associated equipment

9.7.4.3 *Process Strategy*

a) Remineralization

Up-flow type Limestone filters shall be envisaged. The Limestone bed with Continuous Feeding Remineralization where only a portion of the main permeate flow is treated (45-55%) in limestone filter and the remaining flow bypasses it. Both the streams are mixed outside the limestone building. With the up-flow type, the stream passing through the filter receives the hardness necessary for the full flow before mixing with the bypassed flow.

The limestone filters shall have in-built reserve silo in their upper part and series of small feeding funnels placed at the bottom of the silo guide the Calcite from the silo to the surface of the Bed. In this way, the Calcite feeds the Bed by gravity, replenishing it continuously as it becomes dissolved. With such a design, the bed thickness always remains the same.

A backwash system shall be installed for Backwashing the limestone filter, which shall comprise air and water circulation.

b) Disinfection

Chlorine, in the form of sodium hypochlorite (NaOCl), shall be used for disinfection to kill micro-organisms and to prevent biological growth in the transmission line. The point of application will be in the pipeline at the outlet of the limestone beds.

c) LSI

The Langelier Saturation Index (LSI) shall be kept positive within the range of $0 < LSI < 0.5$. For this purpose, sodium hydroxide dosing shall be envisaged.

9.7.4.4 *Automation Control Strategy*

a) Remineralization, Lime Filters

With an up-flow type lime filter system, the permeate stream passing through the filter receives hardness depending on the flow split ratio, pH, and contact time in the limestone bed. The automation control loop shall be programmed to achieve the targeted hardness CaCO3 >80ppm as CaCO3 in the mixed product water outside the limestone filter.

The permeate flow control loop shall adjust the control valve to attain the desired permeate flow rate split ratio based on the number of RO racks running. At the same time, the media level is maintained by gravity filling from the limestone silo. Lime level monitoring to be envisaged in the silo.

The CO_2 dosing shall be a dosing control loop based on the permeate flow to the lime filter to allow the controlled dissolution of the Calcite to obtain the required hardness in the overall product flow.

b) Disinfection
Desalination water product does not require a high level of disinfection chemical dosing, and most of the injected Chlorine will remain as free active Chlorine. Hence dosing of at 1mg/l shall be envisaged for the treated water flow to maintain the residual Chlorine> 0.5 mg/l. The chlorine analyzer shall be provided strategically considering the contact time the signals shall be included in the cascaded control loop.

c) LSI
The final optimal pH is obtained when the Langelier Saturation Index (LSI) is slightly positive (saturation of calcium carbonates) and maintained between 0 < LSI < 0.5. For this purpose, sodium hydroxide dosing shall be envisaged.

9.7.4.5 *Key Operational Monitoring Points*

a) Limestone filter backwash shall be initiated manually by the operator or automatically when the outlet treated water turbidity hits >0.5NTU. RO permeate water shall be used for Backwashing.
The following shall be the minimum procedural steps in Backwashing;
   i. Drain step
   ii. Air scouring step
   iii. Venting step
   iv. Backwashing step
   v. Rinsing step

The Bidder/EPC shall optimize the Backwash step and timing as per performance requirement.

b) Based on the measured parameters, the following configurable alarms shall be provided as a minimum for the effective operation of the post-treatment system, alarms should be configured as a high priority, and associated interlocks should be programmed accordingly:
   - High Turbidity
   - High / Low Hardness
   - High / Low pH
   - High / Low LSI (calculated)
   - High Conductivity
   - High Boron
   - Loss of REMOTE status and Measurements from connected devices

c) Pump Condition Monitoring: The condition monitoring system alarms are to be set as per the OEM limits. All warnings are to be configured as high priority alarms.

d) Dry run protection: The pumps shall be protected from running dry by appropriate hardwired and software interlocks. The level measurement readings are considered the early warning and appropriate actions to be taken by the operator.

e) Other monitoring and safeguarding strategies align with the instrumentation design criteria philosophy referred to in section 9.2.2.

9.7.5 Potable Water Metering System

9.7.5.1 *System Description*

The Potable water Metering system includes two key components

- Potable water Flow Tariff Metering
- Potable water Quality monitoring

9.7.5.2 *Instrumentation & Monitoring:*

a) Instrumentations are to be envisaged as per the instrumentation requirements referred to in section 9.2
b) As a minimum following instrumentation is to be provided:
   i) Main and Check Flow Measurement in the product water line
   ii) Hardness in the product water line
   iii) Chlorine Residual, in the product water line
   iv) Turbidity in the product water line
   v) pH, in the product water line
   vi) Conductivity, in the product water line
   vii) Temperature, in the product water line
   viii) Level, in the potable water tank
   ix) Devices required to monitor the desalination plant-oriented parameters referred to in Indian Water Standard specification "IS:10500-2012 Drinking Water Specification."
   x) Any other device required to meet the operations, guarantee, and environment
c) Instrumentations to ensure the online parameters that product water meets contractual requirements in quality and quantity shall ensure the online parameters.
d) Any other instruments to achieve SWRO Desalination Plant operation, availability, guaranteed performance, operational flexibility, and durability (and service life) of the asset.

9.7.5.3 *Process Strategy*

a) Potable water Flow Tariff Metering
   The potable water delivery pipeline shall be equipped with one main flow meter and one check flow meter connected to the site Metering system for contractual tariff-related readings and connected to the Plant Control System to measure and control plant production flow.
b) Potable water Quality monitoring
   The Quality monitoring arrangement shall be equipped with the required water quality analyzer connected to the Site Metering system for Contractual quality

conformance and connected to the plant control system for measurement, control, and out spec water management.

9.7.5.4 *Automation Control Strategy*

a) Dispatch & Potable water Storage Tank Level
The control system shall be programmed to ensure that the dispatch requirements are always met, the level in the Potable Water Storage tank is always maintained at the required level.

b) Water Quality Management
The control system shall ensure that the water qualities are always within limits. Any abnormal conditions shall be alarmed, and individual action plans are triggered.

9.7.5.5 *Key Operational Monitoring Points*

c) Flow Deviation
The control system shall be programmed to alarm if the main and check flow meter deviation is more than 0.3% at flow rates 15%-49% and 0.25% at flow rates 50% -100%.

d) Following configurable alarms shall be provided, alarms should be configured as a high priority, and associated interlocks should be programmed accordingly:
   - Turbidity - High
   - Hardness – Out of Limit
   - pH – Out of Limit
   - LSI (calculated) – Out of Limit
   - TDS – Out of Limit
   - Boron – High
   - Flow – Low
   - Potable Tank Level – Low
   - Loss of REMOTE status and Measurements from connected devices

e) Other monitoring and safeguarding strategies align with the instrumentation design criteria philosophy referred to in section 9.2.2.

9.7.5.6 *Critical Control Point – CCP 4*

a) Product Water Storage Tank Level Low – 4A
The control system shall incorporate the provisions to alarm when the Potable Water Storage tank level becomes Low. If the level further creeps below Low, the control system shall initiate the sequence to start the required number of RO rack automatically. This RO rack starting shall be coordinated with other process areas through the Plant Level Global Automation sequence programmed in the control system.

b) Product water Quality Limit violation – 4B
When following potable water quality parameter measurements are set limits

referring to the Indian Water quality, the Control system shall incorporate alarm with High priority annunciation.

- Total Hardness
- LSI
- Residual Chlorine
- Conductivity / TDS
- pH
- Turbidity
- Boron

Further, if the measured limits continued to stay after an elapsed time, operator actions specified in the water quality manual must be followed. Appropriate action should be envisaged such that the out-spec water should not reach the product water tank.

Instrument voting on 2oo3 shall be considered for continuous online measurement, and 2oo2 measurement shall be considered for semi-continuous sample aspirated type online measurement.

The Bidder must provide details on out-spec water management procedure in the bid with a summary of the intended operations when the water goes out of specification.

9.7.6 **Outfall**

9.7.6.1 *System Description*

The brine from the RO system and treated wastewater shall be disposed to the outfall facilities, where the treated water is disposed to sea.

9.7.6.2 *Instrumentation & Monitoring:*

a) Instrumentations are to be envisaged as per the instrumentation requirements referred to in section 9.2
b) As a minimum following instrumentation is to be provided:
    - TSS, at outfall tank
    - Residual Chlorine, at outfall tank
    - Iron, at outfall tank
    - Temperature, at outfall tank
    - pH, at outfall tank
c) Devices required to monitor the outfall wastewater parameters referred to in State Pollution Control Board under Water Act 1974.
d) Any other measurement required by the Environmental Approval to ensure there will be no harm to the marine environment;
e) Any other instruments to achieve the Water Quality, SWRO Desalination Plant operation, availability, guaranteed performance, operational flexibility, and durability (and service life) of the asset.

9.7.6.3 *Key Operational Monitoring Points*

a) Following configurable alarms shall be provided, alarms should be configured as a high priority, and associated interlocks should be programmed accordingly:

- TSS - High
- Residual Chlorine - High
- Iron- Out of Limit
- Temperature – High
- pH – Out of Limit
- Loss of REMOTE status and Measurements from connected devices

b) Other monitoring and safeguarding strategies are to be in line with the instrumentation design criteria philosophy referred in section 9.2.2

9.7.6.4 *Critical Control Point – CCP 5*

a) Outfall Wastewater Quality Parameters Limit violation

When outfall wastewater quality parameters are out of limits, the Control system shall incorporate alarming with High priority annunciation. The operator has to take necessary actions by appropriate tuning parameters to bring the parameters within range.

10. INSPECTION AND TESTING REQUIREMENTS

10.1 Inspection and Testing During Manufacture

10.1.1 General

All items of Plant shall be liable to inspection and testing before despatch. Unless otherwise authorised by the Engineer, the Contractor shall arrange routine and functional tests to demonstrate to the Engineer, conformity with the Specification and appropriate Standards.

Inspection and testing witnessed by the Engineer and PMC (termed witness testing) shall be carried out at the manufacturer's works in accordance with the relevant clauses of Clause 7 of the Conditions of Contract.

CMWSSB shall have the right to have their representatives (PMC)/Engineer in Charge/ any other relevant engineer present during inspections and tests of the major equipment and plant systems off-site, on-site tests and during construction. Unless otherwise specified, the Contractor shall submit to CMWSSB a testing schedule for workshop testing and construction testing of all major equipment and systems of the RO Plant at least fifteen (15) Working Days prior to the commencement of such testing. The Contractor shall provide regular updates regarding such testing schedules to CMWSSB. The Contractor shall be responsible for all expenses incurred by the Engineer or Employer's representatives in attending inspection and tests of Plant carried out during manufacture within India and abroad. Maximum 2 persons from Employer and maximum 2 persons from Employer's representative (PMC) will witness the inspection and testing said above.

Witness testing will normally be waived on standard types of equipment such as small motors made by approved manufacturers, individual standardised instruments, small mass produced components used in the manufacture of Plant items, small bore pipework and fittings, minor installation materials and low voltage cable. This shall not relieve the Contractor of his obligation under the Contract to ensure that all Plant is tested at the manufacturer's works prior to delivery to Site.

As a guide to the Contractor, the Engineer will require to witness test of the following, but not limited to the Plant items listed below:

Electrical and Instrumentation:

- power transformers (33 KV/3.3 KV & 3.3KV/0.415 KV)
- 33KV& 3.3 KV switchboards
- MCCs and switchboards
- Capacitor banks with APFCR
- Motors above 20 kW
- Battery and battery charger with DC distribution board

- Power and control cables
- Control and instrumentation
- Plant control and HMI software systems
- DSC/SCADA and PLC
- Control panels
- HMIs
- UPSs

Mechanical:

- All process equipment/ units
- HDPE Pipes, travelling screen and pumps
- Tube settler media
- Clarifier rotating bridge, flocculator and scraper assembly
- Flash mixer
- DAF system
- Filter underdrain system and media
- RO membranes, microfilters, vessels, skid, ERD and pumps
- Metallic tanks and steel structure for warehouse
- Thickener drive, scraper mechanism
- All Chemical dosing systems
- Mixers, pumps and blowers including their motors rated at greater than 20 kW
- Valve and valve actuators
- Valves greater than 300 mm diameter
- Sluice gates and gate actuators
- Chlorination system
- Agitators
- Screens
- Cranes 2 ton and above
- Belt filter press and associated plant
- Piping & specials above 300mm diameter

The Engineer reserves the right to be present during the testing of all Plant items. The Contractor shall carry out tests as stated in the current appropriate Indian Standard; performance tests and such other tests as are necessary, in the opinion of the Engineer /Employer's representatives, to determine that the Plant complies with the Employer's

Requirements either under test conditions in the manufacturer's works, or on site.

The Engineer reserves the right to require the Contractor to meet any costs which are occasioned by failure of the Contractor, in the opinion of the Engineer to take sufficient care before presenting the Plant for inspection or tests. If unauthorised delivery has taken place, the Contractor may be required to arrange for the Plant to be returned to the manufacturer for inspection and/or witness testing by the Engineer at the Contractor's expense.

If the tests are beyond the resources of the manufacturer he shall make arrangements for these to be carried out elsewhere. Any variation of this requirement shall be agreed and confirmation in writing obtained from the Engineer.

Test certificates shall be submitted as part of the QA/QC plan. These shall include all test results, calculations, performance graphs and curves, etc and shall be endorsed by representatives of the manufacturer and the Contractor. No inspection or passing by the Engineer of Plant items shall relieve the Contractor of his obligations under the Contract.

All apparatus, instruments and connections required for the tests shall have been tested for accuracy and safety and certified as such within the preceding six months.

Any equipment used in the testing of the Plant shall in all respects comply with the appropriate safety regulations and/or requirements regarding electrical apparatus for the safety of the Plant and the personnel working thereon.

10.1.2 **Factory Acceptance Test Document/Quality Assurance Plan**

Sixty (60) days prior to commencement of inspection of each Plant item the Contractor shall supply a Factory Acceptance Test (FAT) Document/Quality Assurance Plan (QAP) for review and approval. This shall comprise four copies of the following:

- unpriced copy of the Contractor's order for the Plant item concerned
- details of the inspection and test procedures to be carried out

The FAT Document shall provide comprehensive details of the tests to be carried out, the purpose of each test, the equipment to be used in carrying out the test and the methods to be adopted in carrying out the tests. The FAT Document shall provide space within the documentation for results of the tests to be added and for each test and for the FAT Document as a whole to be signed off by the Contractor and the Engineer.

On completion of the tests the Contractor shall provide four copies of all test certificates, curves etc. for the inspected Plant items. To remove doubt test certificates shall be provided for the Plant items as a whole plus certificates for the relevant component parts such as:

- Power transformers (33 KV/3.3 KV & 3.3KV/0.415 KV)
- 33KV& 3.3 KV switchboards

- MCC s and switchboards
- Capacitor banks with APFCR
- Motors
- Battery and battery charger with DC distribution board
- Power and control cables
- motors
- pumps
- instruments
- gear boxes
- integral control and switchgear panels
- valve gear
- castings
- all types of filter and settling media
- all types of process units
- microfilters
- RO membranes
- RO vessels

Where witness tests are not required the test certificates and curves etc. shall be forwarded to the Engineer within two weeks of the tests being completed.

The Contractor shall not deliver Plant to the site without the Engineer's approval in writing. This permission will not be given unless amongst other things a valid Contractor's test certificate and completed FAT Document for the item of Plant concerned is in the possession of the Engineer.

10.1.3 Inspection and Testing Programme

The Contractor shall submit to the Engineer not later than sixty (60) days prior to the commencement of the first inspection and test during manufacture, a programme detailing the inspection dates for all equipment/units/plants. Those items of Plant that the Engineer has specifically identified for witness testing, shall be highlighted in the programme.

The Contractor shall keep the Engineer/ Employer's representative informed of any changes to the programme.

The Engineer/ Employer's representative shall not be requested to inspect an item of Plant until the Contractor has satisfied himself that the equipment meets all requirements of the Employer's Requirements.

The Contractor shall inform the Engineer in writing at least 21 days in advance regarding readiness for carrying out inspection of equipment/material etc. at manufacturer's works or at places of inspection. The programme for inspection shall be finalised by the Engineer after the receipt of the above. In case inspection cannot be carried out due to non-readiness of equipment/material, etc. a subsequent date shall be finalised for carrying out the inspection and all expenses of the Engineer / Employer's representative for such visits shall be incurred by the Contractor. In case equipment/material, etc. is found not to comply with the specification, dates for re-inspection shall be finalised and expenses incurred by the Engineer for such visits shall also be recovered from the Contractor. Contractor's Representatives shall be present during all inspections. The following information shall be given in the inspection call letter mentioned above:

(a) Name of manufacturer/supplier
(b) Address of place where inspection is to be carried out
(c) Proposed date/s and equipment to be inspected
(d) Name(s) of contact personnel at manufacturer's/supplier's works with their telephone and fax numbers and e-mail address
(e) Name of Contractor's Representative who will be present during the inspection
(f) Confirmation that internal testing has been completed
(g) Testing Procedure with relevant codes and standards

The Contractor shall provide all the necessary instruments to carry out the tests after assembly. All instruments used for such tests shall be calibrated and certified by and approved by an independent testing authority not more than six months prior to the tests in which they are used. Calibration certificates for instruments used for such tests shall be produced for the approval of the Engineer and if necessary, instruments shall be recalibrated before the commencement of the tests.

No material shall be delivered to the Site without inspection having been carried out or unless waived in writing by the Engineer. If during or after testing, any item of Plant fails to achieve its intended duty or otherwise proves defective, it shall be modified or altered as necessary and retested and re-inspected as required by the Engineer at the cost of the Contractor.

10.1.4 **Manufacturer's Works Acceptance Tests on Mechanical Equipment**

The Contractor shall carry out further specified tests (but not limited to) as follows in addition to any tests stated or implied by the foregoing sections of this clause.

10.1.4.1 *Pumps*

Manufacturer's standard test certificates will be acceptable for small centrifugal pumps rated for powers of 20 kW or less.

All other pumps shall be tested individually in accordance with the relevant IS or International Standard. Site conditions shall be simulated as near as possible including the NPSH condition. Pumps shall be tested with their own prime movers. Where it is impractical to include the full length of the connecting shaft, the Contractor shall state the allowances to be made for the losses incurred by its omission and shall demonstrate the accuracy of the allowances to the satisfaction of the Engineer.

Each centrifugal pump shall be tested on the manufacturer's premises individually, in accordance with the provisions of IS 9137/BS EN ISO 9906:2000 with clean, cold water.

Each and every rotating part/assembly/sub-assembly shall be dynamically balanced as per grade G6.3 of ISO 1940/1 - 1986.

Each pump shall be tested at its guaranteed duty point and over its full working range from its closed valve condition to 20% in excess of the specified quantity at minimum head. Tests shall provide information for performance curves to be drawn for: head/capacity, efficiency/capacity and power absorbed/capacity.

Pump casings shall be subject to a pressure test at 2.0 times the pressure obtained with the delivery valve closed. The positive suction head shall be taken into account in determining this pressure. Performance characteristics of motors used during testing shall be furnished prior to commencement of tests.

In addition to confirming the hydraulic performance of the pump set as specified, the test shall demonstrate that vibration is within the specified limits and that the mechanical performance is satisfactory. However, for the purpose of the Performance Guarantee, noise and vibration levels shall be demonstrated at site to be within acceptable limits.

10.1.4.2 *Valves*

Type test certificates will be acceptable for valves sized 300 mm diameter or less.

All valve bodies shall be hydraulically tested closed ended to (minimum) 1.5 times the rated pressure and at rated pressure for seat and duration as specified in IS:14846.

Satisfactory operation of manual/motorised and pneumatic actuators with valves shall be demonstrated.

Butterfly valves' body and disk with rubber seats shall be tested to the pressures and duration as specified under IS:13905.

10.1.4.3 *Penstocks*

Check for smoothness of operation and integrity of seal. Leakage tests shall also be carried out as per appropriate standard. Satisfactory manual and motorised operation of penstocks shall be demonstrated.

10.1.4.4 *Pipework*

The inspection and testing of all pipework shall be carried out in accordance with the appropriate standards approved by the Engineer.

10.1.4.5 *Cranes & Hoists*

Cranes shall be completely assembled and tested for all operations in accordance with the relevant international standard. Internal Test certificates shall be furnished.

Hoists and lifting equipment shall be assembled and tested at the place of manufacture in accordance with IS:3938.

Each and every rotating part/assembly/sub-assembly shall be dynamically balanced as per grade G16 of ISO 1940/1 - 1986.

10.1.4.6 *Compressors*

Tests shall be carried out in accordance with the relevant international standard. All compressors shall be tested with their ancillaries to confirm design performance particularly in respect of flow and pressure. The test shall demonstrate that vibration and noise are within the specified limits and that the pressure relief valve operates correctly.

Air receiver shall be tested in accordance with the relevant section of B.S. 5169. Air dryers shall also be tested as per relevant standards.

All pressure vessels shall be inspected and hydro water tightness tested.

10.1.4.7 *Process Plant Items*

All process Plant items shall be tested to ensure they meet the Employer's Requirements for quality of workmanship, construction and performance.

10.1.4.8 *Chlorine Piping*

All items of Plant shall be tested at manufacturer's works and test certificates shall be provided.

All chlorine gas piping from chlorine drums to chlorinator shall be pressure tested with dry air/nitrogen to a pressure of 15 kg/sq.cm.

The chlorine gas piping from the chlorinators up to injectors shall be pressure/vacuum tested with dry air/nitrogen to a pressure/vacuum equal to 1.5 times the maximum pressure/vacuum to be encountered during operation.

The motive water piping shall be hydrostatically tested for a pressure of 1.5 times the operating pressure or the maximum pump discharge pressure at pump shut off whichever is higher.

After the chlorine system has been completely tested as above, leak proofness tests shall be conducted admitting chlorine gas. Leakages if any shall be identified using ammonia stick. During this test all chlorine leak detectors shall be in place and all safety procedures shall be adhered to.

10.1.4.9 *Ventilation system*

The ventilation system (fans 400mm and above) shall be tested at manufacturer's works to verify the design flow and pressure. For all other fans MTC's shall be furnished for review.

10.1.5 Manufacturer's Works Acceptance Tests on Electrical Equipment

The Contractor shall carry out further specified tests as follows in addition to any tests stated or implied by the foregoing sections of this clause.

10.1.5.1 *Switchgear and Motor Control gear Assemblies*

Switchgear and control gear shall be witness tested as complete assemblies.

Factory built assemblies of 33 KV/3.3 KV/0.415 KV switchgear and control gear shall be tested in accordance with relevant Indian Standards.

Additionally, switchgears and control gear assemblies shall be tested for the following:

(a) Interchangeability - All components of the same rating and construction, designated as draw out or plug-in shall be demonstrated as being interchangeable.

(b) Protection and control circuits - For all forms of current transformer protection, the following information, as applicable shall be made available to the Engineer before the time of inspection:

   - current transformer magnetising curve
   - recommended relay setting
   - calculated primary operating current at this setting
   - calculated through-fault stability values where applicable
   - values of any stabilising and setting resistors employed in the system

As far as possible, based on the completeness of the circuits, in the final manufactured form within manufacturer's premises, the satisfactory operation of associated control and protection circuits shall be proved by the following tests as applicable.

- To ensure the correct operation of all relays and coils at the recommended setting by current injection
- To ensure the correct polarity between current and voltage elements of power relays, meters and instruments
- To ensure the correct operation of control circuits at normal operating voltage by operation of local control switches and simulation of operation from remote control positions

Note: Checking the operation of protection relays and control circuits shall be carried out with all relevant circuits energized at their normal rated voltage.

The following tests shall be carried out:

- Dielectric tests at an approved voltage/s
- Primary injection tests to ensure correct ratings and polarity of current and voltage transformers and of the current operated protection relays and direct acting coils,

over their full range of settings

- Tests on auxiliary relays at normal operating voltages by operation of associated remote relays
- Correct operation of sequencing and control circuits at normal operating voltages by operation of local control switches, and simulation of operation from remote control positions
- Correct functionality of the equipment in all modes of control

10.1.5.2 *Transformers*

Transformers shall be subject to works routine and acceptance tests as defined in the relevant standard. Type test certificates issued within the past three years shall be provided for the following:

- impulse voltage withstand
- temperature rise

10.1.5.3 *Capacitor Bank with APFCR*

The capacitor bank with APFCR shall be subject to works routine and acceptance tests as defined in the relevant standards

10.1.5.4 *Battery and Battery Charger with D.C Distribution Board*

The battery and battery charger with D.C distribution board shall be subject to works routine and acceptance tests as defined in the relevant standards.

10.1.5.5 *Cables*

All cables and armoured cables shall be subject to routine and acceptance tests in accordance with the relevant Indian Standards. Test certificates shall be provided against each drum and/or cable length. The tests carried out on every cable length and/or drum at manufacturer's premises shall include:

- high voltage DC insulation pressure test, between cores, each core to earth, metallic sheath or armour as applicable
- insulation resistance test
- core continuity and identification
- conductor resistance test

10.1.5.6 *Motors*

The manufacturers type test certificate and an individual motor test certificate shall be provided for all motors. All type test certificates shall have been issued within the past three years.

Electric motors shall be subjected to routine and acceptance tests in accordance with relevant Indian Standards.

It shall be responsibility of the Contractor to select sizes, and types of motors to suit the starting and running characteristics of driven equipment with due consideration for specified margin over the requirement of the driven equipment at duty point. Motors not complying with the above shall be replaced by the Contractor at his own cost by appropriate motors. Replacement motors shall undergo testing and inspection as per the provisions in the contract. Cost of such testing and inspection shall be to Contractor's account.

The motor rotor assembly shall be dynamically balanced as per grade 6.3 of ISO 1940/1-1986.

10.1.6 Manufacturer's Works Acceptance Tests on PLC s and Associated Equipment

The Contractor shall carry out further specified tests as follows in addition to any tests stated or implied by the foregoing sections of this clause.

The tests shall be carried out on the fully assembled control panel containing the PLC and associated equipment in order to demonstrate correct functional operation of the hardware and software systems.

The Contractor shall prepare for the approval of the Engineer a detailed Factory Acceptance Test (FAT) document that shall fully detail the scope of the tests to be carried out and the tests themselves.

The tests shall encompass the normal modes of operation and failure modes and shall demonstrate correct functionality of the system or systems in accordance with the Functional Design Specification (FDS).

The PLC program or programs shall be tested by means of a test rig designed to input and receive digital and analogue signals. Using this test rig it shall be possible to fully simulate the operation of the controlled equipment in order to demonstrate correct functional operation of the hardware and software systems.

The analogue to digital conversion shall be tested by means of a calibrated current source, digital to analogue outputs shall be tested by means of ramping the output channel and measuring the current by means of a calibrated current meter.

All inputs and outputs to the PLC and associated equipment shall be made through the field terminal connections of the control panel containing the PLC and associated equipment.

10.1.7 Manufacturer's Works Acceptance Tests on Uninterruptible Power Supplies

The Contractor shall carry out further specified tests as follows in addition to any tests stated or implied by the foregoing sections of this clause.

The tests shall be carried out on the fully assembled unit utilising the batteries that are to be supplied with the unit.

The Contractor shall demonstrate the following:

- change-over from full load with mains present to full load on battery supply
- carry out a discharge test on the system at full load and for the specified duty bridging time period
- carry out recharge test after operation for the specified duty bridging time at full load, the UPS shall supply the full load during the recharge cycle

10.2 Inspection at Site

During erection of the Plant, the Engineer will inspect the installation from time to time in the presence of the Contractor's Supervisor to establish conformity with the requirements of the Specification. Any deviations found shall be corrected as instructed by the Engineer.

10.2.1 Plant Protection on Site

Factory finished Plant shall be adequately protected both before and during installation against damage to finished surfaces, fitted components, and the ingress of dust. It may be necessary for structural finishing operations to be carried out in the vicinity of installed Plant before it is taken over and the Contractor shall take this into consideration in complying with the requirement of this clause.

10.2.2 Erection Staff

The Contractor shall provide at least two approved senior English speaking working erectors to supervise the erection of all Plant in the Contract.

The Contractor shall also provide sufficient erectors skilled in electrical, mechanical and instrument engineering, with such skilled, semi-skilled and unskilled labour as are necessary to ensure completion of the various sections of the Contract in the time required. The Contractor shall not remove any supervisory staff or labour from the site without the prior approval of the Engineer.

The Contractor shall make all the necessary arrangements to ensure that sufficient Plant has been or is about to be delivered to site, so that there shall be no delay to the start of erection.

It shall be the responsibility of the Contractor to obtain necessary License/Authorisation/Permit for work from the Licensing Boards of the locality where the work is to be carried out. The persons deputed by the Contractor's firm should also hold valid permits issued or recognized by the Licensing Board of the locality where the work is to be carried out.

10.2.3 **Erection and Building In**

10.2.3.1 *General*

The installation work shall comply with the latest applicable Standards, Regulations, Electricity Rules and Safety Codes of the locality where the installation is to be carried out. Nothing in this specification shall be construed to relieve the Contractor of this responsibility.

It shall be the Contractor's responsibility to obtain approval/clearance from local statutory authorities including Electrical Inspector, wherever applicable for conducting of any work or for installation carried out which comes under the purview of such authorities.

The Contractor shall carry out the complete erection of all Plant, including the provision of all necessary skilled and unskilled labour, material, transportation, supplies, power and fuel, Contractor's Equipment and appurtenances necessary, for the complete and satisfactory erection of the Plant.

The Contractor shall have a separate cleaning gang to clean all equipment under erection and as well as the work area and the project site at regular intervals to the satisfaction of the Engineer. In case the cleaning is not up to the Engineer's satisfaction, he will have the right to carry out the cleaning operations and any expenditure incurred by the Engineer in this regard shall be to the Contractor 's account.

10.2.3.2 *Erectors*

The Contractor's employees shall include skilled erection staff in sufficient number, who shall arrive on the site on or before the respective dates set out in the approved work programme and prior to delivery of any item of Plant to the Site. The Engineer will not entertain any claim by the Contractor in respect of delayed erection due to a delay in the delivery of any items of Plant to the Site.

10.2.3.3 *Contractor's Equipment, Materials and Appurtenances*

The Contractor shall have available on the Site sufficient suitable equipment and machinery, as well as all other materials and appurtenances required by him, of ample capacity to ensure the proper erection of Plant and to handle any emergencies such as may normally be expected in work of this character.

The Contractor shall be responsible if any installation materials are lost or damaged during installation. All damages and thefts of equipment/component parts, after takeover by the Contractor, till the installation is taken over by Engineer shall be made good by the Contractor.

10.2.3.4 *Workmanship*

Plant shall be erected in a neat and workmanlike manner on the foundation and at the locations and elevations shown on the approved drawings and other engineering documents. Unless otherwise directed by the Engineer, the Contractor shall adhere strictly to the aforesaid drawings and no departures there from shall be permitted.

All Plant shall be correctly aligned, levelled and adjusted for satisfactory operation and shall be installed so that the proper and satisfactory connection can be made readily between the various units and pipework and equipment installed under the Contract. The mounting arrangements for pump sets shall be such that the alignment offset between motors and the driven equipment shall be well within 0.1 mm.

10.2.3.5 *Building-in*

Before commencing any erection work, the Contractor shall check the dimensions of structures where the various items of Plant are to be installed, and shall bring any deviations from the required positions, lined or dimensions to the notice of the Engineer and shall take such measures as are necessary for their correction.

The Contractor shall take particular care for the correct positioning and alignment of all puddle pipes which are required through concrete structures prior to, and during the pouring of concrete.

The Contractor shall pin and plug in the holes prepared, all small clips, plugs, screws, nails, sleeves, inserts, etc. required for fixing electric wires and conduits, small pipework and all other apparatus.

The Contractor shall align all equipment and holding down bolts and shall inform the Engineer before proceeding with grouting-in the item or item concerned. The Contractor shall ensure that all equipment is securely held and remain in correct alignment before, during and after grouting-in.

The Contractor shall properly bed in cement grout each item of Plant or its supporting base resting on foundations, and shall grout-in where required holding down bolts placed in the holes prepared in the foundations. The materials and workmanship used in grouting shall be such as will result in a solid anchoring of foundation bolts and complete filling of the gaps between the Plant or its base and the foundations, without shrinkage or cracking.

10.2.3.6 *Precautions*

The approval by the Engineer of the Contractor's proposals for rigging and hoisting of any item of Plant into its final position shall not relieve the Contractor from his responsibility for avoiding damage to completed structures, parts or members thereof or other installed equipment. He shall at his own cost make good, repair or replace any damaged or injured items whether structural, mechanical, electrical, architectural, or of any other description, promptly and effectively to the satisfaction of the Engineer.

No Plant or other loads shall be moved across the floors of structures without first covering the floors with timber of sufficient size so that applied loads will be transferred to floor beams and girders of steel or concrete. If it is required to reduce bending stresses or deflection, the beam and girders shall be provided with temporary supports. Any movement of Plant and other loads over the floor structures shall be subject to the prior approval of the Engineer.

10.2.4 Inspection after Erection

After the erection of any item of Plant and its associated equipment has been completed, it shall be offered to the Engineer for inspection in its static state prior to commissioning the item.

The mechanical completion of Plant under erection shall be deemed to occur if all the units/systems of the Works are structurally and mechanically complete as noted below :

a) All rotary, static, structural equipment, piping, electrical/instrumentation and other equipment under the scope of the Contract have been erected, installed and grouted and are as per the specifications.

b) All systems have been washed/flushed/drained/boxed up where necessary.

c) All system testing including pressure, vacuum and nondestructive tests, no load tests and such other tests are completed with safety valves/relief valves set to operating conditions installed in position.

d) All panels, local control desks erected with power/control cable terminations with all continuity checks, insulation checks and other installation checks are carried out.

Prior to pre-commissioning checks, the Contractor shall erect the entire Plant and ensure readiness of civil works to the satisfaction of Engineer, so that the Works are physically ready to undergo pre-commissioning checks. Pre-commissioning checks shall include checks like no-load running of machinery, checks on instruments and electricals including calibration and loop checks, functional checks, inter-lock checks etc.

At the stage of mechanical completion of erection, the Contractor shall ensure that all the physical, aesthetic and workmanship aspects are totally complete and the Plant is fit and sound to undergo pre-commissioning checks.

The following documentation shall be completed before the Contractor notifies Mechanical Completion of Erection to the Engineer :

- All shop inspection records compiled and bound in 4 (four) copies.
- All erection and commissioning procedures duly approved.
- All instruction manuals in draft form - with each sheet bearing a stamp to indicate "DRAFT FOR REVIEW ONLY" submitted in 4 (four) copies.

Upon achieving mechanical completion, the Contractor shall notify the Engineer of such completion of section/units/systems and readiness for inspection for acceptance of mechanical completion of erection. The Engineer shall proceed with inspection of such sections/units/systems within 10 days of such notice.

Consequent to inspection, the Engineer will inform the Contractor a list of deficiencies for rectification and the Contractor shall complete the rectification work within a jointly agreed period prior to start of pre- commissioning tests. The erection period allowed by the Contractor shall include all activities of mechanical completion as noted above.

10.2.5 **Site Acceptance Test Document**

Sixty (60) days prior to commencement of Tests on Completion the Contractor shall supply a Site Acceptance Test (SAT) Document for approval. This shall comprise four copies of the details of the inspection and test procedures to be carried out in testing the Works.

The SAT Plan shall provide comprehensive details of the tests to be carried out, the purpose of each test, duration of test, tolerance limits, the equipment to be used in carrying out the test and the methods to be adopted in carrying out the tests. The SAT shall provide space within the documentation for results of the tests to be added and for each test and for the SAT as a whole to be signed off by the Contractor and the Engineer.

The SAT shall categorise tests as follows:

- Pre Commissioning Checks
- Dry Tests
- Wet Tests
    - hydraulic tests
    - process tests (Manual and Automatic)
- Initial Performance Tests

Dry tests are those tests carried out without process fluid being present.

Wet tests are those tests carried out with raw seawater or product water in order to prove the hydraulic capability of the Works. Process wet tests are those tests carried out with raw water as the feed stock to prove the process capability of the various equipment and Works.

Initial performance tests are carried out after Dry and Wet tests to check the performance of the complete process of the Plant as a whole. Both water treatment processes and wastewater treatment processes shall be tested. The tests are described in detail below.

All dry tests and wet tests shall comply with relevant approved International standard/code.

It shall be assumed that the co-operation of other contractors in the carrying out of Tests on Completion will not be unreasonably withheld.

10.3 Tests On Completion

The Tests on Completion referred to in Clause 9 of the General Conditions of Contract shall be read in conjunction with the Clause 3.12 of A3 document of Section VI, Part 2.

The purpose of Tests on Completion shall be to demonstrate and confirm that the Works can fulfil all the mechanical, electrical and process requirements of the Specification. This includes all commissioning and initial performance tests.

Prior to the commencement of Tests On Completion the Contractor shall submit for approval the following along with all the documents required as given in the Part-2, A3 document:

- Site Acceptance Test Documents
- As-Built Drawings
- Operation and Maintenance Manuals

Tests on Completion shall not be commenced until the aforementioned documents are prepared by the Contractor and approved by the Employer.

The initial stocks of oil, grease, chemicals, membrane etc. necessary for Tests shall be kept ready and to be provided by the Contractor. The costs of chemicals, power, spare parts and any other ancillaries used for the Tests shall be met by the Contractor.

The Contractor shall carry out all tests on the Plant and shall supply five hard copies of all test results with one soft copy to the Engineer. The test report shall include recordings of power and chemical consumption and Plant performance/behavior pattern.

All tests shall be to the approval of the Engineer who may require them to be repeated, prolonged or modified as may be necessary to ensure that any or all items of the Plant conform with the Contract. The Engineer shall be permitted to inspect all Plants which are undergoing tests and may himself conduct tests.

Where, it is necessary for the Engineer to make arrangements for the supply chemicals, power, etc., for any testing, the Contractor shall inform the Engineer in writing before at least 3 weeks and not commence the tests until after these arrangements have been made on or after a date agreed by the Engineer and the Contractor shall make no claim for delay to such testing on this account.

If any item of Plant fails during or after testing to achieve its intended duty or otherwise proves defective, it shall be modified or altered or replaced with higher capacity/rating Plant item as necessary and re-tested and re-inspected as required by the Engineer.

Apart from process performance, the vibration/noise level tests shall be carried out at site which will form basis for acceptance of the equipment. If the Contractor is not in a position to meet the requirements given below as per ISO 10816 – 1995, the equipment may either be rejected or the Contractor shall carry out all necessary modifications to keep vibrations/noise within the acceptable limits specified in Table 1.

Table 1: Noise Level as per ISO 10816

Equipment	**Noise Level dBA at 1.86 m from**	**Velocity of Vibration**

	Equipment	mm/sec
All rotating equipment not having reciprocating parts with motor kW less than or equal to 15 kW	85	1.12
All rotating equipment having reciprocating parts with motor kW more than 15 kW and less than or equal to 75 kW	85	1.8
All rotating equipment not having reciprocating parts with motor kW greater than 75 kW	85	2.8
All equipment having reciprocating parts viz. compressors, dosing pumps sampling pumps	85	-

The Contractor shall have a minimum of four commissioning engineers, two for process and Plant and the other two for electrical/instrumentation works on site during all tests in order to demonstrate the Plant and to correct any faults which may occur.

10.3.1 **Pre-Commissioning Checks and Dry Test Requirements**

10.3.1.1 *General*

As a minimum requirement the following checks shall be carried out as a general requirement:

- a general inspection to check for correct assembly and quality of workmanship
- a check on the presence of lubricant, cooling medium, electrolyte, etc.
- a check on adequacy and security of Plant fixing arrangements
- a general check to ensure that all covers, access ladders, water proofing, guard railings etc are in place
- a check on damp-proofing, rust-proofing and vermin-proofing and particularly the sealing of apertures between building structures, chambers etc and the outside

10.3.1.2 *Civil and Building Works*

As a minimum requirement the following dry tests shall be carried out on the civil engineering and building works:

- check for the presence of foreign bodies in pipework and structures.

10.3.1.3 *Mechanical Works*

As a minimum requirement the following dry tests shall be carried out on the mechanical systems:

- carry out preliminary running checks as far is permitted by circumstances in order to ensure smooth operation of Plant

- Monitoring and control from remote workstation.
- Automatic switchover from normal power to emergency power, and emergency power to normal power.
- All control functions, both at local system and remote workstation.
- Operation of all monitoring instruments.

10.3.1.4 *Electrical Works*

As a minimum requirement the following dry tests shall be carried out on the electrical systems:

- check phasing and polarity
- carry out point to point check on all cables
- check on security of cable terminations
- check on completeness and adequacy of earthing systems
- check setting on protection relays, sizes of fuses and motor overload settings
- carry out checks on cabling systems in accordance with the requirements of the relevant standards
- check operation of main circuit breakers by secondary injection methods
- check rotational direction of Plant
- check instrument loop integrity, functionality and calibration
- check Plant functionality
- check functionality of the central HMI and its power supply
- check functionality of the water treatment plant to other communications interface

All control sequences shall be fully tested unless there is potential for damage to the equipment. All safety and protection devices (e.g. flow switches) shall be tested to ensure that they operate correctly.

10.3.2 **Wet Test Requirements**

Wet tests shall be carried out on completion of dry tests and shall comply with relevant approved engineering international standard/code.

Raw seawater or product water (if available) shall be used for hydraulic wet tests. The purpose of the tests is to prove as far as is practical the hydraulic performance of the Works. In order to demonstrate this the Contractor shall ensure that each part of the Works is hydraulically loaded to its rated throughput (including a period of overload if required in order to demonstrate compliance with the Employer's Requirements) for a continuous stable operating period of not less 48 hours.

In order to ensure a sufficient supply of raw water to carry out these tests the Contractor shall provide facilities for the disposal off site in an approved manner not less one third of the Works rated output.

In order to remove doubt the following tests inter alia shall be carried out:

- pressure testing of all piped systems laid direct in ground in accordance with the relevant standards
- fill all structures and check for leaks
- filling of all storage vessels to check for leaks and distortion
- running of all pumped systems in order to check for:
    - correct functionality
    - absence of leaks
    - correct running temperatures
    - smoothness of running and the absence of undue vibration or stress
    - check drive running currents
- carry out calibration of instruments where appropriate
- carry out valving, diversions etc. to fully hydraulically load (or where there is a requirement to withstand an over load to overload) each process element
- manual operation and automatic commissioning tests of all the equipment and protection systems
- manual operation and automatic commissioning tests of all the process units including RO system
- alarm initiation
- demonstrate correct functionality of electrical, control and instrumentation systems
- Verification of conformance to specified or guaranteed performance as far as is practical at the initial loading

The Contractor shall simulate where practical the conditions that will prevail when operating as a process in order to demonstrate the correct functionality of process control loops etc.

During these tests a check on the performance of Plant shall be made, as far as site facilities will allow, to compare its site performance with the factory test data and to identify any constraints on performance due to site conditions.

10.3.3 Safety Audit

After satisfactory completion of wet tests and prior to introduction of process fluid to the Plant a safety audit shall be carried out to ensure compliance with the necessary requirement for safety and for operation of Plant. The safety audit shall be documented. The safety audit document shall be approved by the Engineer prior to commencement of Plant sterilisation.

10.3.4 Plant Sterilisation

On approval of the safety audit document the Contractor shall carry out sterilisation of the wetted parts of the Works. In order to remove doubt this shall also include the wetted surfaces of water treatment chemical storage and dosing systems.

The sterilisation process shall be carried out by completely filling the item or items concerned with water containing not less than 30 mg/L of free chlorine and leaving it to stand for not less than 48 hours. On draining down the Contractor shall demonstrate that the chlorine residual has not fallen below 10 mg/L of free chlorine. If this is not true the sterilisation process shall be repeated until this condition is met.

The Contractor shall be responsible for the disposal of the sterilisation solution. The Contractor shall take the necessary measures to ensure that the free chlorine residual of the solution for disposal is not greater than 1 mg/L before discharge to the environment.

Areas such as the roofs of tanks not easily wetted by filling the vessel with sterilisation solution shall be sterilised using a procedure approved by the Engineer.

The Contractor shall give 2 weeks notice to the Engineer and the Employer of the proposed date for carrying out sterilisation.

The Contractor shall advise the Engineer and the Employer in writing when all wetted parts of Plant and civil structures have been sterilised.

If the Contractor carries out any work that invades a previously sterilised area the Contractor shall be required to carry out re-sterilisation of that area to the approval of the Engineer.

10.3.5 Punch List

Throughout the Start-up, commissioning and testing phase, the Contractor shall rectify minor Defects identified on a Punch List which shall be updated as items are rectified. Prior to Acceptance of the Plant, the Employer's Representative, PMC Consultant and the Contractor shall agree upon the final Punch List identifying all minor Defects which must be completed by the Contractor following Provisional Acceptance of the Plant together with a timeframe for completion of each item.

After completion of the commissioning as per the agreed test program, the RO Plant, including related equipment, systems and facilities, shall be put into a minimum twenty-four (24) hour trial run at various load settings and operating conditions established mutually by the Contractor and Employer's Representative/PMC Consultant. Starts, stops and switching-over to standby equipment shall be included. The Contractor may extend the operating period if it considers this necessary to achieve the quality and stability of operation required for the Initial Performance Test.

However after successful trial run and commissioning, the Employer at his sole discretion may commence commercial operations of the plant to meet the demand, if so is necessary in his sole discretion. During the said period the Contractor shall pay all the cost of the plant operation and maintenance and it will continue till the successful completion of the proves proving.

10.3.6 Initial Performance Test

On approval of the sterilisation process the Contractor shall carry out initial performance tests (test on completion) as per the Clause 9 of GC of Contract. All the cost of the test including labour, power chemical, membranes etc. shall be borne by the Contractor.

The Contractor shall run the Plant as a whole including RO system and sludge processing units in order to demonstrate the full functionality and performance of the Works at various throughput rates for a continuous period of not less than 15 days.

The activities necessary to complete before start-up of the Plant for performance tests shall include, but not be limited to :

i. Completion of buildings and civil works to the extent necessary for the safe and proper operation of the Works;
ii. Testing ventilating and air conditioning units;
iii. Safety audit;
iv. Pressure testing, leak tests, tightness tests;
v. Checking of pipe hangers, supports, guides etc.;
vi. Pipe and equipment flushing and cleaning;
vii. Chemical protection of piping systems, if applicable;
viii. Checking of coating, if applicable;
ix. Testing and adjustment of safety devices;
x. Checking and functionally testing of electrical systems according to IEC standards;
xi. Valid calibration certificate of instrumentation is available, loop checking, functional testing of control equipment, interlocks, protection inputs, etc.; and
xii. Operation of equipment for functional test.

During the various process tests apart from the online water quality measurement, the Contractor shall take samples and carry out water quality analysis at the intervals stated in Table 2 or more frequent as required necessary by the Engineer in order to demonstrate that the Works is functioning in accordance with the Employer's Requirements. Each sample shall comprise two 1 litre (minimum) quantities and shall be labelled to identify the contents, where taken and time and date. One sample shall be used by the Contractor for his analysis, the other shall be handed over to the Engineer.

The Engineer reserves the right to take additional samples and to carry out his own tests or to check the samples taken by the Contractor.

The Engineer shall be given reasonable access to the premises where analysis is taking place in order to check on working practices and the procedures being adopted.

As much as possible, the pre-treatment and post treatment plant shall be operated with minimum automation for at least 3 days during 15 days initial performance test period. Manual operation shall be required to demonstrate the satisfactory operation of the whole Plant at all design flow rates whilst using the minimum quantity of automatic control and monitoring equipment. Such equipment shall be at least that required both for the maintenance of safety and for the normal mode of operation of the Plant.

During the test period; if the power supply should fail or other matters interfere outside the Contractor's control, the tests may be repeated or carried out of such number of broken days as the Engineer considers is the equivalent.

The exact date of commencement shall be subject to the approval of the Engineer and shall be dependent on the following conditions having been met:

- all relevant items of Plant in approved working order
- all items of Plant correctly identified with labels
- the operation and maintenance manual is submitted and approved

10.3.7 **Water Quality Criteria for Passing the Tests On Completion**

The Works shall be considered to have achieved the required water quality standards for passing Tests On Completion if all samples taken during a 15 days continuous operational period comply with the criteria set down in Table-2 for the passing of the Tests, including criteria relating to the reliability of the Plant.

Initial performance tests shall not be commenced until all tests associated with the civil/building, electrical and mechanical works and individual process tests have been completed to the satisfaction of the Engineer. The product water during this period may be taken into public supply network depending on the Employer's discretion.

10.4 Process Proving Test

On successful completion of the commissioning with Initial Performance Tests, the Contractor shall carry out the Process Proving Tests for a period of 90 consecutive days. As much as possible, these tests shall be conducted under both dry (non-monsoon) season and monsoon raw water quality conditions in order to prove the operation of the Works at varying raw seawater quality. During these tests water produced by the plant will be entering the public supply network. The process proving test conditions shall be read in conjunction of the provisions given in A-3, Section VI, Part-2 of Employer's requirements.

The purpose of this test is to demonstrate the performance of the following Works:

- Intake system
- Pre-treatment system
- RO system

- Post treatment system
- Sludge treatment and disposal system
- RO membrane Cleaning (CIP)
- All allied units and buildings

Each part of the Works shall be considered separately as far as the tests are concerned. Obviously, it will not be possible to carry out the Proving Test if all parts are not in service.

The Contractor shall inform the Engineer in writing the date of completion of the Test on Completion (commissioning, initial performance test and the proving test). The total time for carrying out the Proving Tests shall not be less than 90 days.

If there are more than two events of failure when product water quality and quantity is not maintained as specified in the Contract during the 90 days of operation, the test shall be deemed as failed and the test shall be terminated. The Contractor shall carry out necessary remedial work to the satisfaction of the Engineer before the Employer approves to restart the test again. The event of failure is defined as the 2% reduction in production or deterioration of product water quality in terms of TDS, Boron and other vital parameters in a day of 24 hours.

The Contractor will not be held responsible for interruptions to the desalination process as a result of grid power failures (unless as a result of any fault at the Plant) resulting interruptions in the raw water supply etc. which are out of his control. However, the Contractor shall be required to demonstrate that the Works can cope with these inevitable interruptions in an orderly fashion and recover to a normal operational state with the minimum of manual intervention.

All manpower and consumables needed for operation of the Works during process proving period such as chemicals, power, membranes, materials, fuel, equipment, transportation of sludge off the site etc. shall be provided by the Contractor. So the Contractor should include the cost of the plant operation during process proving period in the price bid for capital works.

The Contractor shall provide all facilities and equipment not given in the contract and which are deemed necessary for the Employer to carry out and monitor the Tests on Completion. In order for the Employer to carry out any test to corroborate the performance of the Plant, the Contractor shall be required reasonably to co-operate and co-ordinate his activities with those of the Employer and other subcontractors and bearing all the cost of the tests.

During the tests, the Contractor shall take samples to demonstrate that the Works are performing in accordance with the Employer's Requirements. The procedure for taking the samples shall follow as described in the Tender specifications elsewhere. Samples shall be taken at locations and intervals detailed in Table 2. The results of the Tests on Completion shall be compared and evaluated by the Employer and Contractor. Also test results shall be recorded to demonstrate the power and chemical consumptions are within the guaranteed limits as committed by the Contractor in the technical schedules.

Table 2: Sample Locations and Intervals

Sample	Interval (hours)	Criteria for Passing Code
Raw Seawater at pump station	4	Not applicable
Tube Settler Clarifier effluent from each stream	8	Nr 1
DAF effluent from each stream	8	Nr 2
Filtered water from each stage	8	Nr 3
RO feed water after microfilter	8	Nr 4
RO permeate	8	Nr 5
Pump discharge from clear water reservoir	4	Nr 6
Sludge from sludge balance tank	24	Not applicable
Supernatant from thickener	24	Nr 7
Thickened sludge from thickener	24	Nr 8
Belt Filter Press sludge	24	Nr 9

All above sampling and analysis shall be carried out in the laboratory established in the plant and outside agencies for result confirmation.

10.4.1 Criteria for Passing the Test on Completion

10.4.1.1 *Water Quality Criteria at Different Process Units*

The requirements of the water quality shall be considered to have passed the Initial Performance Test and Process Proving Test if all samples taken during the test period at different process units comply with the criteria set forth in the Table-3 below. Also, the final product water is to meet the criteria given in Part-2 A-1 document and CPHEEO standards for drinking water quality. The water quality criteria are an absolute requirement (i.e. the stated water quality standards must be achieved).

Table 3: Performance Criteria Requirement

Passing Code	Performance Requirement	
Nr 1	TSS TOC Turbidity Colour	< 15 mg/l < 4 mg/l < 10 NTU < 5 Pt-Co Unit
Nr 2	TSS TOC Turbidity	< 10 mg/l < 3 mg/l < 5 NTU

Passing Code	**Performance Requirement**
	Colour < 3 Pt-Co Unit
Nr 3	Turbidity: ≤ 0.2 NTU for 95% readings; and ≤ 0.5 NTU for rest of the time. TSS: 0.0 TOC: < 2.0 pH: 7.0 to 8.5 Residual Cl2 < 0.2 mg/l Colour: < 3 units Pt/Co scale Iron: < 0.05 mg/L
Nr 4	Turbidity: ≤ 0.1 NTU TSS: 0.0 TOC: ≤ 2.0 Residual Cl2 0 mg/l Colour: < 1 units Pt/Co scale Iron: < 0.05 mg/l Manganese < 0.05 mg/l SDI: ≤ 3
Nr 5	TDS: < 330 mg/l Boron: < 1 mg/l
Nr 6	TDS: < 450 mg/l Boron: < 1 mg/l Hardness: ≥ 80 mg/l Faecal Coliforms 0/100 mL (Nil) Total Coliforms 0/100 mL (Nil) Taste and Odour - Unobjectionable
Nr 7	Supernatant Turbidity ≤ 10 NTU Total SS ≤ 200 mg/L
Nr 8	Thickened sludge – 4 to 5 % solids
Nr 9	BFP waste solids – ≥ 25% solid

10.4.1.2 *Product Water Quantity Criteria*

The Works shall have fulfilled the product water quantity criteria if the Works have demonstrated that this can provide the quantity of product water detailed in the Contractors Functional Guarantee over a sustained and continuous period of 90 days during the Process Proving Tests.

10.4.1.3 *Sludge Quality Criteria*

The sludge treatment plant shall have fulfilled the sludge quality criteria if the dried solids content of the sludge produced is as detailed Table-4 over a sustained and continuous period during the Process Proving Test. The sludge quality criteria are an absolute requirement (i.e. the guaranteed sludge quality must be achieved).

Table 4: Sludge Quality Criteria

Criteria Code	Criteria
Nr 7	≥ 25 % dried solids
	@ average solids contents in feed

10.4.1.4 *Operational Cost Criteria*

The Works shall have fulfilled the operating cost criteria if the operating costs determined during the Process Proving Test are in agreement with or less than those detailed in the Contractor's Functional Guarantee or an amount of liquidated damages are agreed by the Contractor and the Engineer to compensate for any shortfall in performance up to an agreed maximum amount as stated.

10.4.1.5 *Plant Reliability Criteria*

Apart from the quality, quantity and operational cost criteria for the test discussed above, a part of the Works shall be deemed to have failed its test if a single item of Plant fails more than twice during the test, or more than four individual Plant items fail. An item of Plant shall be deemed to have failed if manual intervention is required in order to restore the item to its fully operational state (i.e. the failure of a duty drive will be considered as one failure, if the standby drive fails to start that will be considered as a second failure).

10.4.2 **Taking Over**

No item of Plant will be certified for Taking Over under Clause 10 of the General Conditions of Contract by the Employer unless it has successfully passed the Process Proving Test.

A Taking Over Certificate for Plant shall not be issued unless 7 copies of the instruction manuals for operation and maintenance of that Plant and 7 copies of all completion (As-built) drawings with soft copies of all manual, drawing with civil structures have been received to the satisfaction of the Engineer.

The instruction manual complete including SCADA/DCS system for operation and maintenance of Plants shall be in two parts. Part 1 shall detail operation of entire Plant as a system giving sequence of operation, DO's and DONT's very clearly. The operation manual shall be user friendly so as to guide the operator faultlessly in operating the Plant. The manual shall be customized giving details of important information about operation, maintenance and troubleshooting, and it should not be mere collection of manufacturer manuals.

Part 2 shall deal with maintenance of each component of the system, sub-system etc. in full details giving details of construction, material, manufacturer's item code No., dismantling and assembly procedures, dimensions, routine checks to be carried out, signals and observation by predictive maintenance gadgets that can prompt maintenance, overhauling of sub-systems/systems.

The drawings shall give complete details of the systems, sub-systems like dimensions cross-sectional views, assembly details, etc. Maintenance schedules as specified by the manufacturers for each component of the system and for entire system shall be furnished

A Taking Over Certificate defines the start of the Extended Operation and Maintenance period but its issue does not relieve the Contractor of his obligation to the continued satisfactory performance of the complete Works in all aspects.

10.4.3 Operation and Maintenance Period

The Operation and Maintenance Period of 20 years as defined in the Contract shall commence from the date of issue of the Taking-Over Certificate, which will be issued as the Engineer decides appropriate after successful completion of 90 days Proving Period. The detail of the operation and maintenance is provided in the technical requirements A-13, Part-2.

10.5 Performance Certificate

The conditions for issuance of a Performance Certificate as detailed in Sub Clause 11.9 of the Conditions of Contract shall comprise:

- completion of the 20 years operation and maintenance of the Works to the satisfaction of the Engineer
- Operation and Maintenance Manuals have been updated following 20 years of operational experience and as approved by the Engineer.
- all defects identified prior to Taking Over and defects identified during the 20 years operation and maintenance of the Works have been rectified.
- all Tests before Handover have been completed to the satisfaction of the Engineer.
- all training detailed in the Employer's Requirements have been completed

11. GENERAL PAINTING AND PROTECTION REQUIREMENTS

11.1 General

The preparation, application and conditions for work shall comply with the recommendations of BS 5493 and BS 6150 or if the protection is of a special nature, in accordance with the manufacturer's directions.

Paints, primers and undercoats shall be obtained from the same manufacturer and except where a definite time is specified between mixing and application, shall be ready mixed for use. They shall be compatible with one another.

Paints shall be delivered in sealed containers bearing the manufacturer's name, batch number, etc. and shall carry a label giving details of quality and instructions for use.

No site painting shall be carried out unless the surface to be painted is prepared and dried, the air temperature above 4^{o}C and the relative humidity less than 85%. The Engineer / Employer's Representative shall approve the methods for removing all dirt, oil, grease, etc, before painting commences. No paints in any coat shall be applied until the Engineer/ Employer's Representative is satisfied that the surface is clean and dry. After cleaning when a surface is approved for painting, it must be painted immediately. Unless the manufacturer's instructions state otherwise 48 hours drying time shall elapse between successive applications of any primer and 24 hours between applications of all subsequent coats. The surface of bituminous paints shall be left at least 3 days before further handling.

Test plates carrying finishes from the actual coating used may be required by the Engineer for inspection and test purposes.

To facilitate inspection, no consecutive coats of paint shall be of the same shade except in the case of white. Priming to two mating surfaces shall be applied prior to assembly.

All items of Plant shall be delivered to Site with the shop paint finish applied unless specified otherwise. A further coat of final finish paint shall be applied at Site, of sufficient thickness to produce a uniform colour and appearance and also to fix any damage to the painting during transport. Such painting shall be carried out within one month of successful acceptance trials for the Plant.

All paint dry film thicknesses shall be checked using an alkometer or equivalent instrument, supplied by the Contractor, for each layer of paint, to the satisfaction of the Engineer / Employer's Representative.

No paints in any coat shall be applied until the Employer's Representative is satisfied that the surface is clean and dry, and that any previous coat is satisfactory and has hardened adequately. When a surface has been approved, it must be painted immediately. Paintwork shall be rubbed down with a glass paper between coats. No paint shall be applied to a surface which is damp, dirty or otherwise inadequately prepared.

11.2 Colour Coding and Labelling of Pipes and Equipment

All pipes and equipment shall be colour coded to a schedule to be agreed with the Engineer before any site painting starts, or earlier if necessary, to suit manufacturing procedures. Valves and fittings shall be painted in the same colour as the pipe of which they form a part. Where a pipe enters or leaves a piece of equipment the pipe colour shall extend up to but not including the flange attached to the equipment.

All pipelines shall be identified by stick-on 90 micron thick vinyl film labels showing the name of the material to be carried by the pipeline and an arrow indicating the direction of flow. Letters of titles shall be pre-spaced on carrier tape and the complete title protected by one-piece removable liners. Titles shall be at intervals not less than 8 m, but shall in any case be provided in every space through which the pipe passes. Locations of labels shall be subject to prior approval by the Engineer. Lettering sizes shall be between 16 mm and 75 mm in height depending on the size of the pipe.

Pipes smaller than 22 mm outside diameter shall be labelled by the use of tags instead of labels. Tags shall be made of brass no smaller than 65 mm x 16 mm by 1.5 mm thick, with lettering etched and filled with black enamel. Titles shall also be provided on all equipment in locations and in sizes to be approved by the Engineer.

11.3 Cleaning and Preparing at Place of Manufacture

The Contractor shall be responsible for the cleaning and preparation for painting, priming or otherwise protecting as specified of all parts of the Plant at the place of manufacture prior to packing.

11.3.1 Cleaning

Parts shall be cleaned prior to testing at the manufacturer's works. Parts subject to hydraulic test shall be tested before any surface treatment. After test all surfaces shall be thoroughly cleaned and dried out if necessary, by washing with an approved dewatering fluid prior to surface treatment.

11.3.2 Preparation

Bright parts: Bright parts and bearing surfaces shall be thoroughly polished and protected from corrosion by the application of rust preventive lacquer or high melting-point grease, as approved by the Engineer, before the parts are packed. A sufficient quantity of the correct solvent for removal of the protective compounds shall be supplied and packed with each particular part.

Embedded parts: Embedded parts or those parts of an assembly which will be embedded in concrete shall be thoroughly de-scaled and cleaned to the satisfaction of the Engineer and before being packed shall be protected by a cement wash or other approved method. No cast iron or steel work shall be bitumen or tar coated where it is to be cast into the concrete and provision shall be made for cleaning off any portions so coated.

Grit or shot blasted parts: Grit or shot blasting shall be carried out in accordance with BS 7079 to a standard between `First Quality' and `Second Quality' given in Table 1 after which the maximum amplitude of the surface shall not exceed 0.1 mm.

Cast Iron and Steel pipework: All ungalvanized steel pipework including pump suspension mains, bearing spiders and tunnel tubes shall be prepared internally and externally by grit or shot blasting as specified above and the surfaces primed as specified within four hours of blasting.

11.4 Painting and Finishing at Place of Manufacture

This Clause governs the methods for the protective coatings to be applied to structural steel, metalwork and ironwork as corrosion protection systems. Protective coating specified elsewhere for particular works such as pipes and cladding shall firstly be designed in accordance with particular requirements specified elsewhere and secondly in accordance with any requirements herein which are not overridden elsewhere. This specification makes reference to the following standard: BS 5493 "code of practice for the protective coating of iron and steel against corrosion".

The Contractor shall design each protective coating system and shall submit details of each system to the Engineer for approval. Submissions shall where possible be in the format of which examples are given at the end of this part with such additional information and samples as the Contractor may provide or the Engineer may require to enable the system to be assessed.

Protective coating shall be designed in accordance with BS 5493 to have a long life, generally of at least 10 years prior to first maintenance. Protection systems shall be chosen to be easily maintained in the future and to allow non-specialist on-site re-coating where necessary using single part paints.

For the purposes of system design the general environment shall be as specified in BS 5493 Table 3 Part 2 `Exterior exposed polluted inland'. Bulkhead gates and stoplogs shall be assumed to be exposed to a Table 3 Part 8 `Non-saline water' environment unless otherwise approved by the Engineer.

Interior spaces shall be considered to be dry in administration areas open to continuous access and damp or immersed in other spaces. The protective coating of components or structures which are continuously or infrequently immersed shall be designed for the more onerous of these two conditions relevant to the protection system used.

All exterior exposed items to be coated shall have a final coat of good appearance of a colour and type as approved by the Engineer.

Protective coating systems shall generally fall into one of the following basic systems:

- galvanising
- galvanising plus painting
- multi-coat painting

- bitumen enamel
- others as proposed by the Contractor and approved by the Engineer

The Contractor shall submit to the Engineer details of his proposals for the corrosion protection of each of the items requiring such protection, which will generally fall into the above categories as follows:

- trash screens, flooring, ladders, access covers and frames, step irons and other components which are inaccessible but subject to abrasion/damage
- structural steelwork (including crane beams, monorails, crane structures and chassis), bulkhead gates, stoplogs, grappling beams, steel tanks and other large items readily accessible for maintenance
- valves and other corrosion-susceptible items which may be buried and are not covered by the provisions of other specifications
- other components not covered by the above for which the contractor may propose a system which he considers to be more suitable for the duty
- electrical switchgear, transformers, control panels etc.

All painting material shall be applied in strict accordance with the paint manufacturer's instructions.

11.4.1 **Plant Supplied to Site with Final Coating Applied**

Cubicles, Cabinets etc.

Before any steel work is painted the steel must be thoroughly cleaned and an approved anti-rusting priming coat applied so that the possibility of rusting or corrosion taking place is negligible. All surfaces should have not less than two undercoats and two top coats or air-drying paint. The undercoats shall be easily distinguishable in shade or colour form the priming and finishing coats. The two final coats shall be in a colour and finish to be advised by the Engineer. The inside surfaces of any cubicles, cabinets, etc. where condensation is liable to occur, shall be coated with an approved anti-condensation composition. The Contractor shall ensure that all component sections of a switch board wherever manufactured shall have a finish of uniform texture and an exact colour match.

Chromium Plated Parts

Where chromium plating is specified or offered by the manufacturer it shall comply with the requirements of BS 1224 including the following provisions. No blistering of any surfaces will be tolerated. The finished appearance shall be bright. Where the base metal is steel, plating shall be applied in accordance with Table 2 of the above code. Other base metals shall be plated in accordance with Tables 3, 4, 5 as appropriate. For all base metals the service condition number 2 (of the above code) shall be used. Small bore pipes, valves and fittings etc., which are sited in architecturally finished areas of the station and selected by the Engineer shall be chromium plated. Damage to chromium plating shall be made good before taking over.

<u>Galvanised Parts</u>

All materials to be galvanised shall be of the full dimensions shown on the approved drawings or specified and all punching, cutting, drilling, screw tapping and the removal of burrs shall be completed before the galvanising process begins. Parts to be galvanised shall be shot blasted as specified above. Such parts shall be galvanised not more than four hours after commencement of shot blasting.

All galvanising shall be done by the hot dip-process. No alternative process may be used without the approval of the Engineer. No components shall be galvanised which are likely to come into subsequent contact with oil.

The zinc coating shall be uniform, clean smooth and as free from spangle as possible. In the case of component parts the zinc coating shall weigh not less than 610 g/sq. m of area covered and shall not be less than 0.090 mm in thickness.

Bolts and nuts shall be standardised. The Engineer may select for test as many components to be weighed after pickling, and before and after galvanizing as he may think fit.

All galvanised parts shall be protected from injury to the zinc coating due to differential serration and abrasion during the periods of transit, storage and erection. Damaged areas of the coating shall be touched up with an approved zinc-dust paint or other approved flake metallic compound.

<u>Cast Iron and Steel Pipework (Internal Surfaces)</u>

The internal surfaces shall have an approved coating. Where a bitumen-based coating is used, it shall be in accordance with Type 2 of BS 4147.

Prior to lining, the pipe shall be grit blasted and primed with an approved primer. The lining shall be in accordance with BS 534. After installation, the internal lining shall be made good and satisfactorily tested with a Holiday detector to 8 kV.

The coating shall be suitable for use in contact with drinking water. The type of coating shall be entered in Schedule L provided and the Engineer reserves the right to call for test plates of the paint. The manufacturer shall at the time of ordering carry out the `Taste and smell test' (Appendix E of BS 4147) and `Effects on water test' (Appendix C of BS 3416) and forward 3 copies of the test results to the Engineer for approval.

Where pipe are to be welded after the protective coatings have been applied the pipe surfaces shall be primed and all other coating stopped 250 mm short of the weld preparation. Collars and fillings shall be primed but no other coating applied.

The manufacturer shall supply a sufficient quantity of suitable materials to repair damage occurring during delivery to site and to provided a flush finished internal lining at welded joints. He shall supply sufficient coating to fill in the recesses at internal welds over the previously primed areas. The costs of these materials shall be included in the unit rates for the supply of the pipes and specials. The coating shall be applied in accordance with the manufacturer's instructions and with Appendices J and K of BS 3416.

<u>Cast Iron and Steel Parts (External Surfaces)</u>

All ungalvanized metal parts which will be immersed in water shall be cleaned by grit blasting and within four hours of blasting given a approved coating. Ungalvanized metal parts exposed in manholes or areas of high humidity shall be cleaned by grit blasting and given two coats of a black bituminous solution.

11.4.2 **Plant Forwarded to Site for Final Finishing**

<u>Cast Iron and Steel Parts (External Surfaces) Outside Buildings</u>

All ungalvanized metal parts which will be exposed to the outside atmosphere shall be cleaned by grit blasting and provided with two coats of an approved primer.

<u>Cast Iron and Steel Parts Inside Buildings</u>

All exposed metal surfaces which will not be immersed in water or exposed in areas described above shall be rubbed down, cleaned by grit blasting and within four hours of blasting given one coat of an approved primer before packing.

11.5 Painting at Site

Immediately on arrival at the site, all items of plant shall be examined for damage to the paint coat applied at the manufacturer's works, and any damaged portions shall be cleaned down to the bare metal, all rust removed, and the paint coat made good with similar paint.

Steel and cast-iron parts received at site shall be provided with adequate number of further coats of coal tar epoxy polyamine coating or Polyurethane coating as specified & approved, to a total dry film thickness of minimum 275 microns including the primer coats unless specified somewhere else. All sharp edges, nuts, bolts and other items difficult to be painted shall receive a brush coat of specified paint before application of each coat of epoxy-based coal tar paint giving a total dry film thickness of at least 275 microns. In the case of fabricated steelwork this work shall be done after assembly.

Before painting is commenced the Contractor shall submit for the approval of the Engineer, full details of the paints he proposes to use together with colour charts for the gloss finishes.

After erection, such items which are not finish painted shall be finish painted, items finish painted at the Manufacturer's works shall be touched up for any damaged paint work.

The painting work shall conform to the following requirements:

(a) The surface preparation shall be carried out generally in accordance with IS: 1477 Part I and IS: 6005.

(b) After surface preparation, two coats of primer-red oxide zinc chromate with modified phenolic alkyd base conforming to IS: 2074 shall be applied. Dry film thickness of each coat shall be 25 microns.

(c) For finish painting, after application of primer as in (b) above, two coats of synthetic enamel conforming to IS: 2932 shall be applied. Dry film thickness of each coat shall be 25 microns.

(d) Colours shall be selected as per IS: 5

No painting shall be carried out unless the item has been inspected and accepted by Engineer at the Manufacturer's works.

The dry paint film thickness shall be measured by Electrometer or other instruments approved by the Employer. In order to obtain the dry film thickness DFT specified, the Contractor shall ensure that the coverage rate given by the paint manufacturer will enable this thickness to be obtained. Strength of adhesion shall be measured with an adhesion tester and this value shall not be less than 10 kg/cm^2. Painted fabricated steel Work which is to be stored prior to erection shall be kept clear of the ground and shall be laid out or stacked in an orderly manner that will ensure that no pools of water or dirt can accumulate on the surface. Suitable packings shall be laid between the stacked materials. Where cover is provided, it shall be ventilated.

The painting procedure shall be submitted in the following format for approval:

(a) Surface Preparation
(b) Reference Standard
(c) Conditions of Work
(d) Type of Materials
(e) Tests and inspection methods and sequence, thickness (DFT)
(f) Colour in final coat
(g) Total thickness of coats (DFT)
(h) Other necessary data and information

The following items in the plant are required to be painted:

(a) Outer surfaces of pumps, valves, pipes, fittings, motors etc., not exposed to treated water
(b) Steelwork exposed to weather, such as outer surface of surge vessel, valves, pipes etc.
(c) Internal Plant and pipework, cranes, exhaust fans, fire extinguishers and miscellaneous steelwork not exposed to weather
(d) Steelwork exposed to weather, such as platforms, ladders, hand railing, etc.
(e) Steelwork exposed to humid weather and requiring hard maintenance and repairs
(f) Buried steelwork
(g) Buried pipes and fittings prior to application of wrapping
(h) Other equipment, as per requirement of employer.

All buried steel pipes and fittings shall be coated and unwrapped with hot or cold applied, self-adhesive, polyethylene in accordance with AWWA C214 or equivalent Standard.

Cast iron or mild steel parts to be built into concrete shall remain unpainted. Immediately before it is cast in-situ, it shall be made perfectly free from dirt, scale, loose rust, paint, oil limewash or any other coating.

No blast cleaning or painting shall be applied to corrosion resistant Materials such as stainless steels. Ni-resist cast iron, bronze and other metals used for seals, bearings, lighting fitting etc.

Machined surfaces such as gear teeth shall be coated with a thick layer of grease. Other mechanical surfaces such as shaft ends or other bright parts shall be coated with two coats of an anti-rust solution which can be removed easily when required. Permanently bolted mechanical interfaces such as flanges shall be coated with a thin coat of anti-rust compound before assembly.

All primers, under coats and finishes shall be applied by brush or airless spray, except where otherwise specified.

Consecutive coats shall be in distinct but appropriate shades. All paints shall be supplied from the store to the painters, ready for application, and addition of thinners or any other Material shall be prohibited. Any instruction given by the paint manufacturer shall be strictly followed.

All painting shall be carried out by the painters under supervision. Paint shall be applied to the dry surface which has been prepared in compliance with the approved procedure.

Paint shall not be applied when the ambient temperature falls below 4ºC or relative humidity rises above 90%.

The plant and equipment shall be inspected and reviewed at the various stages of the coating application both at the manufacturer's works and at the site of the Works. Samples may be taken from the paints as delivered and submitted to such tests as are deemed necessary. The completed paint systems shall be tested by instruments to ensure that the protection is of adequate thickness and is free from pinholes and the direct measurement of adhesion shall be checked by the removal of a small section of the coating. The Contractor shall supply all instruments and apparatus required for carrying out such tests required by the Employer.

11.6 Waterworks Finish

A high standard of finish, defined as "Waterworks finish" is required for all Plant as detailed below.

11.6.1 Welding and Flame Cutting

A smooth neat finish, by careful grinding if necessary is required on all exterior welding and flame cutting. All plates and bars used in fabrication shall have smooth surfaces with no pitting or deep slag inclusions.

11.6.2 Castings

Casting surfaces shall be smooth and free from surface blowholes. Stock castings shall be selected with this in mind. All castings shall be shot blasted before machining.

11.6.3 Covers

All covers shall be firmly fixed. Weld mesh shall sit square in its frame. Where panels are placed next to each other the patterns shall line up.

11.6.4 Flanges and Beadings

All bolt holes shall be spot faced parallel with the mating face for good seating of nuts and bolt heads. Surplus jointing shall be removed from mating faces and peripheries.

11.6.5 Items to be Chromium Plated

Name plates, instruction plates, rotation arrows, indicators and pointers, small bore pipework, tundish oil level gauges and fittings, small valves (including air valves), plugs and grease nipples, which are sited in architecturally finished areas of the station and as selected by the Engineer, shall be chromium plated. Damage to chromium plating shall be made good.

All pipes and fittings, etc. shall be fitted in a straight, neat symmetrical manner so as to present a pleasing appearance.

11.6.6 External Screws, Bolt-heads, Nuts and Washers

These shall be chromium plated, sherardised or made in stainless steel.

11.6.7 Gauges

All indicating gauges fitted to any machine assembly shall be of similar appearance and grouped together to present a pleasing aspect. They shall all have chromium-plated cases, bezels, cocks and fittings.

12. TRAINING AND ADVISORY REQUIREMENTS

12.1 Training Requirements

12.1.1 General

The Contractor shall provide comprehensive training for the different categories of the Employer's operation and maintenance staff. Training shall fall into two main types which are 'off the job' and 'on the job'. Off the job training shall take place in the class room, on the job training shall be carried out at the operating treatment plant.

12.1.2 Off -the Job Training

The Contractor shall prepare formal training documentation for distribution to the trainees. Visual aids shall be used where possible to illustrate the points being made and to make the training programme as interesting and enjoyable as possible for the participants. The off the job training shall comprise the following:

12.1.2.1 *Off the Job Training Programme for all Trainees*

a) simple chemistry and process principles involved in the operation of the Works
b) details of the processes involved including comparison with other processes
c) plant operational procedures and trouble shooting
d) health and safety
e) use of the local and central HMI's

12.1.2.2 *Off the Job Process Training Programme for Operators*

a) operation of individual items of plant and sections of the Works including automatic operation and manual operation in the event of say automatic control failure
b) day to day operation of the Works and procedures
c) comprehensive list of 'what if' scenarios dealing with the actions to be taken in the event of potential process problems, alarms, plant failures, overflows, power failures. etc.
d) first line mechanical maintenance
e) safe methods of work general
f) safety procedures to be followed in operating, maintaining and cleaning the plant
g) special precautions to be followed in the event of a chlorine leak

12.1.2.3 *Off the Job Training Programme for Electrical Maintenance Staff*

a) configuration, construction and operation of the electrical plant
b) electrical maintenance requirements of the Works
c) switching and safety procedures to be followed
d) safe methods of working

e) fault finding and repair procedures

12.1.2.4 *Off the Job Training Programme for Control and Instrumentation Maintenance Staff*

a) configuration, construction and operation of the plant
b) control and instrumentation maintenance requirements of the Works
c) fault finding and repair procedures
d) safe methods of working
e) special training on the use of the PLC and associated programming software for fault finding on PLC based control systems
f) special training on the use and performance of the central HMI SCADA hardware and software and other specialist hardware and software systems used on the plant

12.1.2.5 *Off the Job Training Programme for Mechanical Maintenance Staff*

a) routine mechanical maintenance requirements of the Works
b) lubrication requirements of the Works
c) fault finding, repair and overhaul procedures
d) safe methods of working

12.1.2.6 *Off the Job Training Programme for Desalination Management Staff*

a) desalination process management techniques
b) desalination plant cost management
c) desalination plant laboratory management
d) safe methods of work general
e) safety procedures to be followed in operating, maintaining and cleaning the plant

12.1.3 On The Job Training

The Contractor shall utilise the Operation and Maintenance manuals as the primary training aid in carrying out the on the job training. Short comings, omissions and errors identified in the Operation and Maintenance manuals during the training shall be rectified prior to final acceptance of the Operation and Maintenance manuals.

12.1.3.1 *On the Job Training Programme for all Trainees*

a) plant familiarisation tour
b) use of the local and central HMIs
c) plant safety procedures
d) identify areas where special safety precautions are necessary

12.1.3.2 *On the Job Process Training Programme for Operators*

a) operational conditions on the operation of individual items of plant and sections of the Works including automatic operation and manual operation in the event of say automatic control failure

b) illustrate by example the day to day operation of the Works and procedures

c) illustrate by example the actions to be taken in the event of potential process problems, alarms, plant failures overflows, power failures etc. (as identified in the 'what if' scenario off the job training)

d) illustrate by example the first line mechanical maintenance

e) illustrate by example safety procedures to be followed in operation, maintenance and cleaning of the Works

12.1.3.3 *On the Job Training Programme for Electrical Maintenance Staff*

a) carry out detail tour of the electrical plant

b) illustrate by example the operation of the electrical plant

c) illustrate by example the electrical isolation and maintenance procedures

d) illustrate by example fault finding and repair procedures

e) illustrate by example switching and safety procedures to be followed

f) illustrate by example safe systems of work

12.1.3.4 *On the Job Training Programme for Control and Instrumentation Maintenance Staff*

a) illustrate by example the operation of the Works

b) illustrate by example the control and instrumentation maintenance requirements of the Works

c) illustrate by example fault finding and repair procedures

d) illustrate by example fault finding on PLC based control systems, the central HMI SCADA hardware and software and other specialist hardware and software systems used on the plant

e) illustrate by example safe systems of work

12.1.3.5 *On the Job Training Programme for Mechanical Maintenance Staff*

a) illustrate by example the routine mechanical maintenance requirements of the Works

b) illustrate by example lubrication procedures

c) illustrate by example fault finding, repair and overhaul procedures

d) illustrate by example safe systems of work

12.1.4 **Training Programme**

Off the job training shall be carried out prior to the commissioning of the Works or any section of the Works. With the permission of the Engineer and the Employer on the job training shall be carried out prior to start of the operation and maintenance. On the job training shall be completed as a condition for acceptance of the Works following completion of the Tests After Completion.

The Contractor shall provide a training plan for each category of staff. The training plan shall detail the content and duration of each course. The training plan shall be submitted for the approval of the Engineer at least 120 days prior to the commencement of the training program. The duration of training offered for each category of staff shall not be less than that detailed in the Table 1.

Table 1: Minimum Duration of Training Courses

Category of Staff	**Off the Job (minimum days duration for each course)**	**On the Job (minimum weeks duration for each course)**
All staff	1	1
Operator	5	5
Electrical technician/electrician	3	5
Control/instrument technician	5	10
Mechanical technician/fitter	3	5
Desalination plant operation team	5	(see note)
Desalination plant management	3	(see note)

Note: It is assumed that desalination plant operation/management personnel on the job training will be available throughout the 240 months when the plant is operated by the Contractor.

The training day shall be assumed to be not less than six hours split into two sessions. The off the job training rooms shall be provided by the Employer at the Site in existing buildings. The Contractor shall provide facilities for training which shall include inter alia tables and chairs, projectors, white/black boards, training aids, etc. Where trainees of a given category can all be released from their operational duties simultaneously they may be trained together. Where this is not possible the Contractor shall repeat the complete course for those who could not attend.

12.1.5 **Training Personnel**

The Contractor shall provide suitably qualified trainers to carry out the off the job and on the job training. The trainers are to be experienced in desalination plant management, operation and maintenance in their relevant discipline and in the training of skilled and unskilled staff. The Contractor shall submit the curriculum vitae of the nominee for the position of training expert to the Engineer for approval 120 days before training is scheduled to commence. The training expert shall be fluent in English, Tamil and Hindi or the Contractor shall provide the services of an interpreter(s) during the training periods.

12.2 Advisory Requirements

12.2.1 General

The Contractor shall provide personnel to advise in the operation of the Works for a period after Hand Over. The personnel provided shall have proven experience in their intended roles. Those persons provided shall comprise:

- Advisor to the treatment works manager duration 24 months
- Advisor mechanical maintenance duration 6 months plus 2 months
- Advisor electrical/control maintenance duration 6 months plus 2 months
- Advisor process duration 6 months plus 2 months

The electrical/control, mechanical and process specialist visits are split. During the first visit procedures shall be established and implemented. During the second visit, the procedures shall be monitored and refined. The role of the Contractor's advisory personnel shall be to:

- advise on day to day management of the desalination plant
- advise on the development procedures for the ordering and reordering of consumables
- propose and develop systems to monitor the consumption of consumables and power and to advise actions to reduce their usage to a minimum
- establish analytical procedures within the laboratory and carry out periodic checks to ensure that they are adhered to
- establish routines for the analysis of water quality in all areas of the plant and to establish procedures for corrective action in the event of quality falling below that expected
- establish systems for the recording of water quality appropriate to a plant of this type
- ensure procedures for operation and planned maintenance of the Works as detailed in the Operation and Maintenance manuals are carried out
- advise on the optimisation of process settings, dosage rates, operating regimes etc.
- provide continuing informal on the job training to the Employers staff (this is in addition to formal training requirements detailed elsewhere)
- update the Operation and Maintenance manuals in line with experience gained during the year's operation

The Contractor shall be responsible for all costs associated with the provision of the his advisory personnel.

12.2.2 Advisory Personnel

The Contractor shall provide suitable personnel to provide advisory services. The advisors shall be experienced in desalination plant management, or operation and maintenance in their relevant discipline. The Contractor shall submit the curriculum vitae of the advisory nominees to the Engineer for approval 120 days before scheduled assignment. Prior to mobilisation, the advisors shall be fluent in both Tamil, Hindi and English or the Contractor shall provide the services of an interpreter(s) during the advisory period as necessary.

12.2.3 Operation and Maintenance Manual

This Operation and Maintenance manual shall be provided by the Contractor to establish guidelines for plant operators to understand the new desalination plant to operate this system efficiently and successfully. The guidelines will be provided to the training personnel, on how to operate the plant so that they shall be able to manage to treat the water to best quality; with low consumption of energy; with low cost of maintenance; providing a long life of equipment; protection against accident, safe working methods and protecting systems from damages.

The system operation and unit operation of each component will be needed to be adjusted and modify depending on the raw water quality and the required data are collected during the training program as well as operation and maintenance period. The Contractor shall train the CMWSSB personnel about Plant operation knowledge, abilities and skill as follows:

12.2.3.1 *Capacity Building*

Knowledge:

- System flow and unit operation, maintenance, pumps, blowers, other plant equipment and machinery
- Basic Desalination Process
- Basic sludge handling principle and its characteristics
- Basic maintenance period and work sheet
- Basic laboratory techniques to make standardized tests
- Avoiding any chance of accident
- Basic safety and health

Abilities:

- Make adjustments to desalination system according to Raw water characteristics and its flow fluctuation, and control
- Make adjustments to control the chemical dosing system
- Adjust chlorination process, and to lift sacks of chemicals and to read and follow written and oral instructions
- Adjust dosing system of chemicals. Perform standardized laboratory tests
- Make repairs and/or adjustments to water treatment equipment and to keep records and prepare reports
- Make repairs and/or adjustments to each equipment and to keep records and

prepare reports

- Handling safety valves and its pipeline
- Read and interpret gauges and recording devices used in the desalination plant
- Usage of safety Equipment in case of Emergency

12.2.3.2 *Tasks of Operation and Maintenance Works*

a) Operate water treatment plant under normal conditions such as equipment, machinery and pipe line, including valves, gate, stop-logs, pumps, thickeners, chlorine feeder, chemical tanks, dewatering equipment, chemical preparation and dosing system, reading flow meter; regulate flow of water, disposing the sludge, etc.

b) Select the desalination facility or equipment to meet actual inflow pattern

c) Take samples and make standardized laboratory test if required, including tests for temperature, residual chlorine, pH, turbidity and other required items

d) Set the system/equipment to adjust timer or operation period to meet the required specified amounts of feeding chorine solution, chemical solution, air volume, sludge withdrawal, recycling waste wash water

e) Make minor repairs and adjustments to machinery, equipment, pipes and other materials pertinent to the operation of the plant

f) Work on troubleshooting including bulk flow control

g) Maintain maintenance and operational records

h) Cleaning of machinery, equipment and civil tanks, building, loading and unloading of materials and storage of chemicals properly

i) Does general maintenance of the plant, including, but not limited to, painting, general custodial work, maintenance of equipment, etc

j) Assist in repairing flow meters and pipe line including valves in inactive time and/or operation time

k) Assist in the inspection of all necessary equipment, of water & wastewater sampling & of pipe line

12.2.3.3 *Information to be covered in the Operation and Maintenance Manual*

The Operation and Maintenance Manual shall be prepared in accordance with the information provided in Part-2 A3 works requirements. The manual should include but not necessarily be limited to the following:

a) Background of project
b) Plan and design condition
c) System operation indices and unit operation indices
d) Water Quality & Quantity (Inlet/outlet):
    - Actual
    - Standard
e) Outline of system operation (Civil, Mechanical & Electrical):

- Summary
- Flow diagrams, plan view, hydraulic profile, Piping isometrics
- Operation flow diagram
- Table of facilities
- (Tag number, Type, Number, Nominal bore, capacity, motor rating, weight)

f) Outline of component and its aim (Civil & Mechanical):
- Normal operation
- Emergency operation
- Selection of facility
- Selection of Auto/Manual mode
- Notice of danger/peril/hazard

g) Verification items of system operation mode (Civil & Mechanical):
- Before start of system operation
- Start of system operation
- During regular operation
- Set value of level sensors and safety pressure on safety devices
- Position of plant/equipment on the selected mode
- Remove potential danger/peril/hazard

h) Details of facility/equipment component (Civil & Mechanical):
- Summary
- Specification
- Outside dimension
- Weight, quality of material
- Outside drawing
- Graph, charts, performance curve, table
- Photo after installation
- Notice of danger/peril/hazard

i) Verification items of component operation (Civil & Mechanical):
- Preparation before the operation
- Starting operation flow
- Normal operation
- Set value of level sensors and safety valves
- Emergency maintenance
- Notice of danger, peril, hazard

j) Outline of component and its aim (Electrical):
- Verify incoming power Hz, kWh
- Verify output from cogeneration Hz, kWh
- Ordinary line or emergency line operation
- Detail and full operation procedure
- Select standby generator
- Emergency operation
- Selection of facility

- Notice of danger/peril/hazard

k) Verification items of system operation mode (Electrical):
- Before start of system operation
- Start of system operation
- Set value of level sensors and protection
- Select Auto/Manual mode on central control panel
- Remove potential danger/peril/hazard

l) Detail of facility component (Electrical):
- Summary
- Specification
- Single line diagram
- Panel dimension
- Weight, quality of material
- Outside drawing
- Graph, charts, performance curve, table
- Photo after installation
- Notice of danger/peril/hazard

m) Facility verification items (Electrical):
- Preparation before the operation
- Select Normal operation or Emergency operation
- Select equipment operation mode/switch by Auto /manual
- Before start of system operation
- Start of system operation
- Set value of level sensors and protection
- Remove potential danger/peril/hazard
- Notice of danger/peril/hazard

n) Standard:
- Water quality at inlet and outlet
- Emission control
- Noise and vibration

o) Fire/explosion protection

p) Dewatered cake sludge handling/disposal

q) Frequency of sampling, analysis and evaluation:
- Inflow and outflow quality /flow rate
- Regulated pollutants
- Operation index
- Amount of sludge and its density
- Water/sludge temperature

r) Maintenance schedule (Mechanical & Electrical):
- Routine work
- Regular work
- Manufacturer recommendation

s) Maintenance schedule(Civil):
- Routine work
- Regular work
- Manufacturer recommendation

t) Calculation sheets:
- Calculation of dosing amount (Alum/Chlorine/Poly/etc.)
- Calculation of sludge amount

u) Troubleshooting guide (Phenomenon/action/comments):
- Discharge quality and bulking
- Process and system control
- Mechanical equipment
- Electrical equipment
- Case study or/and previous experiences (Normal troubleshooting)

v) Operation/test data:
- Operation index
- Mechanical site inspection data
- Electrical site inspection data
- Water quality and quantity(inlet/outlet)
- Regulated pollutants
- Amount of sludge and its density
- Amount of cake and its density
- Noise and vibration
- Water/sludge temperature
- Power /chemical consumption
- Operation cost during training period
- Performance test of pressure control valves, pressure reducing valves
- Consumables, spare parts and its list
- Photo of inspection (evidence)

w) List:
- Equipment control
- Operation record formats
- Maintenance record formats
- Material control
- Inventory
- Spare parts
- Safety and Health

13. OPERATION AND MAINTENANCE

13.1 General

This section applies to the specifications of materials used for operation and maintenance, the workmanship, period for operation and maintenance, specifications for the acceptable quality of product water, maintenance of records, and responsibilities during Operation and Maintenance period. The Contractor shall operate and maintain the desalination plant and sludge treatment systems at Perur, Chennai, the instrumentation system, the communication system, 33 kV/3.3 kV/415 V substations, SCADA/DCS systems, all ancillary buildings and campus area for a period of 20 years. The Operation and Maintenance period shall only commence only after issue of Commissioning Certificate.

13.1.1 Duties and Responsibilities

- The Employer will provide only chemical and power up to the guaranteed quantities given in technical schedule for Functional Guarantee, Part-2 during the 20 years of operation and maintenance period. The remaining responsibilities lie with the Contractor.
- The obligation of Contractor is to provide product water meeting all the quantity and quality specification requirements.
- The Contractor shall manage plant operations so as to limit power consumption and chemical usage to within the specified functional guarantees.
- The Contractor shall ensure satisfactory operation and maintenance of the Works so that the plant operation provides reliable, consistent performance and is economical at all times.

13.2 Definition of Maintenance

Maintenance of the Works covers all the techniques and systems which, by means of regular monitoring of equipment and scheduled maintenance procedures, prevent failures and, in the event of problems, carry out repairs with minimal disruption of the process. Maintenance is therefore a combination of technical, administrative, and management activities. Maintenance consists of preventive and corrective procedures.

13.2.1 Preventive Maintenance

Preventive maintenance consists of all the regular works carried out in order to sustain the conditions necessary for smooth operation of the plant and to keep the performance of the equipment as close as possible to its original performance level. Its purpose is to reduce the probabilities of failure or deterioration of equipment of the plant. In simple terms, preventive maintenance involves the elementary operations such as lubrication, mechanical servicing, and electrical and instrumentation servicing.

13.2.2 Corrective or Remedial Maintenance

Corrective or remedial maintenance of the Works consists of all works needed to re-establish the conditions necessary for an apparatus or set of equipment to operate properly subsequent to failure or deterioration of the results produced by the equipment. It includes the following operations:

- Dismantling of equipment
- Replacement of parts

The work may be scheduled for the short or medium term in accordance with the checks carried out as part of the preventive maintenance procedure, the number of hours an apparatus has been operating, or an alarm factor (abnormal noise, repeated cut-out, weakening of the insulation, etc.) or may be dictated by an unexpected breakdown.

13.2.2.1 *Maintenance work*

The maintenance work consists of inspection work and maintenance work as mentioned below:

- Inspection work, that includes physical appearance, inspection, measurement and testing equipment to verify and survey that the plant performance whether operation is normal or not.
- The inspection work shall be executed daily by each technical specialist as a routine and/or regular inspection and shall be recorded each time. The evaluation on the collected data shall be immediately reviewed by the chief operation engineer to instruct the staff member for operation on the same day and/or make a plan of detail inspection and/or make repair schedule to ensure continuous plant operation without any problem
- Maintenance work, for which main task-work shall include activities, such as lubrication, overhaul and replacement of parts

13.2.2.2 *Operation work*

The operation work is the execution of the plant operation based on the processes and procedures to meet design criteria including set up or adjustment of the operational index or data according to the water quality or demand.

Monitoring work is to confirm the operation data, and readout its measurement value on panels, and check-up the working performance of plant appropriately, as well as maintaining records of the output.

13.3 Specification

The specification of materials used for repairs shall be the same as have been used in the original work. Specifications for any materials which were not used during construction shall be approved by the Engineer prior to commencement of the operation and maintenance period and must be incorporated in the Operation and Maintenance manual. Without being limited by this clause, during Operation and Maintenance period the Contractor shall use appropriate material for repairs even if material required for such repairs has not been approved earlier, and no delay in making such repairs shall be subjected to such limitation. However, subsequent to use of such material the Contractor shall submit proposals for the approval of specifications of such material. The approved material will subsequently form a part of the Operation and Maintenance manual. The comprehensive information as detailed in Table 1 shall be submitted to the Engineer.

Table 1: List of Execution Schedule

Items	Description
Maintenance of plant/facilities	List of unit process, capacity of equipment, method/frequency of maintenance
Operation of plant/facilities	List of plant/equipment, items to be monitoring/operation, preparation of chemical, handling sludge, method of system control, data input into computer, operation of backup, period of power failure and generator operation, communication method etc.
Monitoring of product water quality	Scope of monitoring, method of sampling and analysis, place of laboratory and name of authorized personnel.
Countermeasure against accident and risk management	Damage prediction, simulation of public relations, method of recovery, contact address, rescue activity and emergency team
Renewal	Replacement of pipe, replacement of equipment and facilities
Subcontracting	Method of contract out, scope of works, limit of responsibility.
Evaluation and report	Method of data analysis, evaluation of collected data, improvement program, reporting
Organization and administration	Executive organization chart, segregation of duties, list of staff members, experience, health certificate of staff member, type of insurance, criminal record, personnel name of taking record and make soft data, method of data control, operation and maintenance cost.

13.4 Activities during Operation and Maintenance Period

13.4.1 General

Within the framework of the Contractor's responsibilities given above, the Contractor shall carry out the following activities. However, these shall not limit the requirement for other activities which otherwise are required as per term and conditions of Contract or to fulfil the Contractor's responsibilities or are essential as per good practices. The Contractor shall be responsible for, but not limited to, the following:

a) Providing product water with quality as specified and at the production rates as directed by the Contract

b) Providing the required staff, but not less than the minimum specified numbers/level, during operation and maintenance period and additional staff as per requirement during periodic maintenance and in emergencies.

c) Providing all consumables required for functioning of plant and equipment except for power charges up to the guaranteed limit. In case the power consumption is above the guaranteed value, the Contractor shall pay for the excess in accordance with the Contract Data. The Contractor shall arrange for the chemicals and use at the plant. The Employer will pay the cost of the chemicals to the Contractor based on actual chemical consumption up to the guaranteed quantities. The Contractor shall provide the chemical flow rates and other consumption evidence in support of the actual consumption values.

d) Maintenance of 33 kV/3.3kV/415V substations, etc., pumping stations, pre-treatment units, RO desalination plant, chemical houses, post treatment units etc. in neat and clean condition.

e) Entering into AMC contracts with system/equipment suppliers, as necessary. It is mandatory to enter into an agreement for a 20 years maintenance contract with the PLC and DCS system suppliers or the authorized system integrator, whosoever has executed the work for this project and their representative should be available at site within 24 hours.

f) Maintenance of the lighting fixtures and the lighting system of all areas and replacement of all non-functional lighting fixtures within 24 hours.

g) Maintaining the following:

- Repair history of all mechanical, electrical and instrumentation control equipment in pumping stations, desalination plant, and communication instruments
- Logbooks through PLC system
- Daily log of operations of all the important equipment
- Raw and clear water quality test results on turbidity, residual chlorine levels and other process parameters and sludge quality test results (Refer Part 11, Table 11.2)
- Daily list of alarms with time tag
- Logbook format and the data to be included in the logbook shall be decided during commissioning in consultation with Employer
- Last periodic maintenance done for all equipment/buildings of the system

- In addition to maintenance of above logbooks the Contractor is required to maintain one inspection book at each pumping station and filter plant. The complaints entered in the complaint register must be investigated and remedial measures must be taken immediately.

h) Providing required spares, special tools and test equipment and maintaining adequate inventory of required accessories or equipment itself for repair of system so that the electrical, mechanical, instrumentation and control system, pipe and the communication system can work efficiently as per the guarantees given or minimum required efficiencies asked for in the Contract, without any additional cost to the Employer. The Contractor may use spares and tools and tackles supplied with the Contract as required by him. However at the end of the Contract the Contractor shall hand over the full spares, tools and tackles (as per the schedule provided in Part-1 "Schedule 8: Spare Parts, Accessories and Tools") as supplied with the Contract by replacing the items used during operation with fresh supplies of the same specifications.

i) Providing manpower for the required repairs of all plant facilities along with the manpower and materials for repair of the roads, buildings and campus area utilities.

j) Maintaining the drinking water supply facilities at the desalination plant campus and all its units.

k) Maintaining stores for the electrical, mechanical and instrumentation and control equipment as well as that for the chemicals and laboratory consumables at the filter plant. The maintenance of stores shall include but not be limited to:

- Loading/unloading of materials received and issued for works
- Proper arrangement of material in stores to ensure safety and easy availability
- Maintaining store areas in a neat and tidy condition
- Keeping records and accounting for the incoming materials
- Keeping records and accounting for the consumed materials

The Contractor shall be solely responsible for the safety and security of the goods in the store and shall be responsible for any loss or damages in stores for any reason. He may opt for insurance cover against the value of the goods to be stored without any additional cost to the Employer.

l) Periodic routine maintenance of structures/buildings of campus area of the treatment plant and others built in the Contract. Such maintenance must ensure adequate cleanliness, ventilation, illumination and structural safety. In addition to this, the general hygienic standards must be maintained and adequate plantation, horticultural activities must be taken up to maintain the total environment of the campus/buildings pleasant.

m) Updating and periodic submissions of the operation and maintenance manual as defined in this specifications for Operation and Maintenance works. The Contractor shall take up all periodic maintenance works provided in the approved Operation and Maintenance manual.

n) Submission of monthly report:

- Co-ordination with other contractors and/or agencies responsible for the execution, operation and maintenance of the clear water pumping plant
- The Engineer shall be entitled to audit any aspect of the system and the Contractor shall ensure remedial action as directed
- Safety reporting: Brief reports of all accidents and hazardous incidents including descriptions of cause, extent of injuries, action taken, and precautions instituted to prevent repetition of such events

o) Insurance: The Contractor shall, without limiting his or the Employer's obligations and responsibilities, ensure:

- The work together with material and plant for incorporation therein, to the full replacement cost (term "cost" in this context shall include profit)
- The Contractor's equipment and other things brought onto site by the Contractor, for a sum sufficient to provide for their replacement at the site
- The insurance shall be in the joint names of the Contractor and the Employer at the Contractor's cost and shall cover the Employer and the Contractor against all losses or damages from whatsoever cause arising from the start of the Operation and Maintenance until the date of completion of Operation and Maintenance in respect of the facility or any section or part thereof as the case may be
- Any amount not insured or not recovered from the insurer shall be borne by the Contractor

p) The typical main inspection items and some signs of deterioration of plant are presented in Table 2, which may be observed during routine inspection or monitoring work. The maintenance works shall be planned to gather and analyse information to solve the problem.

Information about raw water quality and product water is absolutely necessary to make a decision how to operate plant operation properly, and to check the operational performance whether the water quality meets water quality standards or not. Typical parameters to be sampled and its quality analysis shown in Table 3. The other tables are:

- Table 4: Typical Operation & Maintenance items in Electrical and Instrumentation Systems
- Table 5 Operation & Maintenance for Mechanical Systems

Table 2: Typical Indication of Sign of Plant Deterioration

Parameters	**Concrete and Structure**	**Pipe Line**	**Mechanical & Electrical**	**Chemical**	**Instrumentation**
Deterioration of material quality	• Appear crack on concrete structure • Water leakage • Scouring • Wear/abrasion • Corrosion (steel, rebar) • Irregular subsidence • Change of shape • Reducing service life	• Appear corrosion (reducing wall thickness/size/bolts) • Electrical corrosion • Water leakage • Damage • Wear/abrasion • Cavitations erosion • Discoloration • Reducing service life	• Stop operation • Heating • Oil/water leakage • Voltage reduction • Lower performance • Electricity failure • Malfunction • Wear/abrasion • Noise/vibration • Electric leakage • Decline acid proof/water proof • Mechanical down • Burnout/damage • Corrosion/rust • High pressure gradient across membranes	• Chemical/water/air/CO_2 gas/ Chlorine solution leakage • Insulation deterioration • Corrosion/rust • Wear/abrasion • Zero-point disparity • Increasing in measurement error • Difficult to adjust accuracy • Failure of total accuracy • Performance defect • Equipment malfunction • Mechanical down • Dosing malfunction • Reducing service life	• Insulation deterioration • Corrosion/rust • Wear/abrasion • Zero/point disparity • Increasing in measurement error • Difficult to adjust accuracy • Failure of total accuracy • Performance defect • System malfunction • Mechanical down • Burn up relays • Reducing service life • Remove puddle/keep dry

Parameters	**Concrete and Structure**	**Pipe Line**	**Mechanical & Electrical**	**Chemical**	**Instrumentation**
			• Reducing service life		
Deterioration of water quality	• Contamination of water by inflow hazardous/waste material, small animal, higher turbidity and pH • Settlement of floating substance • Deterioration/peel-off of internal coating • Spoil the facility • Algae growing on tank inside wall • Low residual chlorine cause of rising water temperature or stagnant water	• Water contamination • Red/black water • Abnormal water color & smell by algae • Low residual chlorine by water quality or stagnant water • Deterioration of internal coating or pipe/peel-off • Observation of metal color in water (Fe, Mn, Cu, Pd)	• Quality analysis • Observation of small flocks • Accumulate sludge on tank bottom • Increasing flocks carry-over • Clogging surface of filter • Crack on surface of filter media • Poor product water quality • Fall of residual chlorine • Reduction of treatment capacity • High permeate TDS	• Failure of agglutination process due to raw water quality • Failure of disinfection dosing rate or process control (lower or higher residual chlorine) • Feeding rate • Volume, color, small at feeding points • A number of equipment as operation • Deterioration of stocked chemical • Generation of THM	• Spoil, consummation, damage, dirty on sensor of measuring devices • Inappropriate installation of measuring devices • Malfunction of measuring devices • System malfunction • Chut-down plant or stop equipment • On-off emergency alert • Defect of operation mode • Failure of indication & accuracy • Remove puddle/keep dry

Parameters	**Concrete and Structure**	**Pipe Line**	**Mechanical & Electrical**	**Chemical**	**Instrumentation**
			• Abnormal water color • Stop & adjust number of operation facility		
Reduction of water quantity and pressure	• Lack of water tank storage capacity • Water leakage • Lack of water tank elevation • Accumulation of bottom • Settlement • Clogging filter media/under-drain/strainer • Blockage inlet/outlet opening by obstacle	• Reduction of pipe diameter due to corrosion • Scale growing • Increasing head loss • Declining water velocity • Declining water quantity • Accumulation of silt, • Air accumulation • Lack of supplying water quantity	• Amount of receiving raw seawater • Water contamination • Declining production quantity • More filter's back wash or shorter filtration life • Uneven backwash or high initial filter loss head • Increasing pump head loss	• Defect of pumping, mixing, making solution. • Declining chemical dousing rate at points • Lack of storage capacity • Failure of agglutination process • Failure of disinfection • Control plant operation	• System malfunction • Malfunction of measuring devices • Control plant operation • On-off pump operation • Water hammer

Parameters	**Concrete and Structure**	**Pipe Line**	**Mechanical & Electrical**	**Chemical**	**Instrumentation**
			• Readout o water meters or water level • Number of pumps on duty or On-off operation • Failure of equipment • Service life of facility • Control supply water • Water hammer		
Decline in plant/system performance	• Decline in retention time • Increasing dangerous unit operation • Difficult to repair • Declining facility efficiency • Increasing operation cost	• Required longer repair work • Defect value/gates operation • Impossible of water flow control	• Increasing frequency of out of order • Increase in frequency of CIP • Longer repair time • Increasing electricity failure	• Increasing frequency of out of order • Longer repair time • Declining operational performance • Poor ventilation & odor • Poor mixing • Increasing third person fault (create ripple	• Shaky system • Increasing frequency of out of order • Longer repair time • Declining operational performance • Missing/lack of operational/maintenance data & record remove puddle/keep dry

Parameters	Concrete and Structure	Pipe Line	Mechanical & Electrical	Chemical	Instrumentation
			• Declining operational performance • Poor flash mixing & flocculation • Accumulation of sludge cake in site • Increasing third person fault (create ripple accident by electricity failure)	accident by chlorine gas leakage)	

Table 3: Typical Parameters for Water Analysis

Parameters	**Location and Sampling/Analysis Points for Water Quality**						
	Raw Water	**Lamella Effluent**	**DAF Effluent**	**GDMF Effluent**	**RO Feed**	**RO permeate**	**Product Water**
Turbidity	Online	Online	Online	Online	Online	Online	Online
pH	Online	Online	Online	Online	Online	Online	Online
TOC	Weekly	Weekly	Weekly	Weekly	Weekly	-	-
COD	Weekly	Weekly	Weekly	Weekly	Weekly	-	Weekly
BOD	Weekly	Weekly	Weekly	Weekly	Weekly	-	Weekly
Alkalinity	Daily	Weekly	Weekly	Weekly	Daily	Online	Daily
Total Hardness	Daily	Weekly	Weekly	Weekly	Daily	Online	Online
Total Dissolved Solids	Daily	Weekly	Weekly	Weekly	Daily	-	Daily
Elec. Conductivity	Online	Weekly	Weekly	Weekly	Online	Online	Online
Iron	Daily	Daily	Daily	Daily	Online	-	Daily
Total Coliforms	Daily	Weekly	Weekly	Weekly	Daily	Daily	Daily
Water Temperature	Online	-	-	Online	Online	Online	Online
Total suspended solids	Daily	Daily	Daily	Daily	Daily	-	Daily
Residual Chlorine	Online	Online	Online	Online	Online	-	Online
SDI	Daily	-	-	Online	Online	-	-

Parameters	**Location and Sampling/Analysis Points for Water Quality**						
	Raw Water	**Lamella Effluent**	**DAF Effluent**	**GDMF Effluent**	**RO Feed**	**RO permeate**	**Product Water**
ORP	-	-	-	-	Online	-	
Boron	Daily	-	-	Online	-	Daily	Daily
Oil & grease	Daily	Daily	Weekly	Weekly	Weekly	-	-
Odour	Daily	Weekly	Weekly	Weekly	Weekly	-	Daily
Taste	Daily	Weekly	Weekly	Weekly	Weekly	-	Daily
Colour	Daily	Daily	Daily	Daily	Daily	-	Daily
Ammonium nitrogen	Weekly	Weekly	Weekly	Weekly	Weekly	-	Daily
Algae	Daily	Weekly	Weekly	Weekly	Weekly	-	-
Nitrate	Weekly	Weekly	Weekly	Weekly	Weekly	-	-

Table 4 : Typical Items in Electrical and Instrumentation Systems

Daily		**Periodic**	
Frequency	Description	Frequency	Description
Transformer	Verification of kVA, V, Am, current protection, oil temperature	Every 6 Months	Verification of oil, abnormal sound, performance
Incoming Panels	Verification of kVA, V, Am, lamp test /replacement, moisture cut heater, current protection, burned smell, remove water	Every 6 Months	Verification of switch On/Off, Fuse, abnormal sound, condenser, relays, protection devices, earthling, wiring and connection
Control Panels	Verification of V, Am, lamp test & replacement, moisture cut heater, overload protection, operation mode, burned smell, remove water	Every 6 Months	Verification of switch On/Off, Fuse, abnormal sound, condenser, relays, protection devices, earthling, wiring and connection
Lighting Panels	Verification of Am, light test & replacement, moisture cut heaters, overload protection, remove water	Every 6 Months	Verification of switch On/Off, Fuse, abnormal sound, condenser, relays, protection devices, earthling, wiring and connection
Meters reading	Verification of V, Am, overload protection	Every 6 Months	Verification of over load protection indication, switch On/Off, accuracy, damage
Motors	Verification of burned smell, heating, vibration	Every 6 Months	Verification of switch On/Off, earthling, insulation resistance, rpm, damage, temperature
System	Verification of system sequence ON/OFF	Every 6 Months	Verification of All system, insulation resistance

Cable line	Verification of short circuit, cable colour, damage	Every 6 Months	Verification of wire droop, degradation, insulation resistance

Table 5 : Typical Items in Mechanical System

Activity	Frequency
Monitoring of Cartridge Filter differential pressure	Online
Monitoring of RO membrane differential pressure	Online
Maintenance on ERI unit	Within 6 hours
Removal of clogged materials from screens	Daily
Cleaning of level sensors	Weekly
Checking vibration and noise level of pump/blower sets	Weekly
Fully closing and opening of sluice gates and valves	Monthly
Replacement of bearings	Within a day of breakdown
Replacement of bulbs, lamps etc	Within a day of breakdown
Tightening of gland	When leakage increases beyond acceptable limit
Greasing, oiling	As per manufacturers recommendation
Preparation of list of spares for satisfactory operation	Semi-annually
Transformer oil sample checking	Semi-annually
Checking of relays/ alarm (trough secondary injection)	Yearly
Condition of gasket and replacement (if required)	Yearly
Operation of crane for all motions	Weekly
Submission of report on maintenance to Employer	Monthly

13.4.2 Experience & Qualification of Staff

For all operation and maintenance works, the Contractor shall provide skilled staff, which has adequate qualifications and sufficient experience of similar works. CV of General Manager, Shift-in-charge, Plant Supervisors shall have to be approved from the Employer. The following Table 6 describes the minimum levels of staffing, and their minimum qualifications and experience in similar works, that the Contractor shall be required to deploy for carrying out the Operation and Maintenance functions:

Table 6: Minimum Requirements for Staff and Qualifications

Sr. No	Designation	Qualification	Experience	Shift-1	Shift-2	Shift-3	Reliever	Total Nos.
1.	Plant Manager	Graduate Engineer (Civil/Env/Chemical)	>15 years	General shift 1				1
2.	Sr. Operation Manager	Graduate Engineer	>10 years	1				1
3.	Operation Manager/ Shift-in-charge	Graduate Engineer (Elec/Mech/Chem)	5 years	2	2	2		6
4.	Maintenance Incharge	Diploma (Elec/Mech/Instr)	5 years	2	2	2		6
5.	Maintenance Personnel	Diploma (Elec/Mech/Instr)	5 years	2	2	2		6
6.	SCADA Operator	Diploma (Engg)/ Science Grad	5 years	2	2	2		6
7.	Field Operator	Diploma (Elec/Mech)/ Science Grad	5 years	8	8	8		24
8.	Admin Staff	Graduate	5 years	2				2
9.	Chemist	B. Sc-Chemistry	5 years	1				1
10.	Lab Assistant	Diploma in Lab Tech.	2 years	3	3	3	1	10
11.	Helpers	10th pass	-	16	10	10	1	37
12.	Safety Officer	Skilled		1			1	2
13.	Security Guards	10th pass	2 years	6	2	2	1	11
14.	Drivers	Skilled	2 years	2	1	1	1	5
15.	Gardener/Cafeteria cleaning	8th pass	2 years	8	4	4	2	18
	Total			14	4	4		136

Notes:

1. The above requirement is minimum only. The Contractor shall arrange extra work force, as and when required, so as to smoothly run the operation and maintenance including preventive maintenance, repairs etc. and general cleanliness of the installations.
2. The above staff strength is exclusive of leave reserve required for different category of staff. The Contractor shall ensure availability of the personnel given in the above table for all seven days in a week.
3. The Contractor shall make appropriate arrangements for maintenance of items like road work, buildings, arboriculture, patrolling and maintenance of civil structures, vehicle operations and other activities defined to fulfil its obligations under Operation and Maintenance Contract.
4. In the event of absence of staff during the Operation and Maintenance, the deduction of payment shall be done on per day basis for the number of days absence. A day salary shall be calculated from the man-month rate quoted by the bidder, considering 30 calendar days in a month.

13.4.3 Safety and Health

a) Chlorination

- All personal who are assigned to work on chlorine storage and injection system shall first be trained to understand and follow all aspects of handling and safety procedures.
- Chlorine handlers shall be instructed to report any condition that may affect their personal health to their superiors.

b) Electricity

- All the electrical equipment shall be handled and operated by a trained and authorized person only. All the equipment shall be checked for its proper earthing and loose connections prior to start equipment. Naked wire, loose connections and faulty connections shall be repaired immediately prior to start for operation.
- Electrical sockets and switch shall not be touched by bare or wet hands. If there is any live wire found naked or on wet ground, main switch shall be turned off first then the wire shall be repaired or moved.
- For any electrical works proper insulated tools shall be used. Do not try to use tools made for other purpose; it may be hazardous.

c) Fall Protection

- Only authorized person shall work at high place, people working at high level shall be very careful and protect himself from fall and injuries. Protective gears such as gloves, safety belts shall be worn and safety belts shall be tied to proper location prior to start the work. If anybody feels dizzy and drowsy he should not work at high and should come down immediately.

- Whenever possible a ladder shall be used. Ladder shall be in stable condition and proper slope of the ladder is 4 vertical and 1 horizontal and it shall be secured at the base.
- All the openings shall be secured properly by a barrier of a hand rail to avoid unauthorized person getting in. Whenever covers are provided for opening those covers shall be kept closed all the time, except for maintenance type.

d) Entering Tank

- If worker should enter inside of deeper manholes or tanks precautions shall be taken.
- Manholes covers shall be open and wait for fresh air to circulate.
- Prior to enter-oxygen level inside the tank shall be checked otherwise it may be hazardous. If oxygen is not enough a ventilating fan should use to supply fresh air inside.
- Only permitted person shall work inside, while a person is working inside there must be another person watching outside; unless he appoints next person he should not leave from duty. While men working inside manholes must keep open and manholes shall be protected from outsiders to go inside.
- If person inside feels drowsy, dizzy or unusual feeling he should come out immediately. He should take rest and take a fresh air.
- If the worker is collapsing inside, do not immediately enter inside for rescue him as as you may be next victim of accident. Prior to rescue make sure that oxygen is enough inside, report immediately to person in charge. Try to rescue the person from outside.

e) Health Checkup

Water can be scrapped and become a carrier of water borne disease if it is handled by an ill person. That is why personal health is an important factor to keep the water potable. Any person not feeling well shall report to their superior and shall be go through proper health checkups. All workers should go through medical checkup every year, and the result of check up shall be reported to the Engineer.

f) General Hygiene

Persons working for seawater treatment and desalination shall maintain a high level of personal hygiene. This includes clean work clothes, skin, fingernails and hair. They should wash their hands properly by using soap and clean water prior to handle the water treatment works.

g) Uniform

All workers at site work shall wear helmet, safety shoes, regular uniform to avoid any accident by rotating equipment.

13.4.4 **Job Description**

Plant Manager

The Plant Manager shall be in charge of all aspects linked to the performance of the operations contract. He shall have authority to carry out or have carried out all tasks involved in the smooth operation of the installation he manages. The Plant Manager will:

- Recruit staff
- Organize work
- Order chemicals and local supplies, including negotiation of supply contracts
- Assume full responsibility for ensuring compliance with safety regulations
- Handle the relations with the customer and inspection bodies
- Implement the resources required for compliance with treatment guarantees.

Operation Manager

The Operation Manager shall be directly under the orders of the Sr. Operation Manager. He shall be accountable for the treatment performance of the unit for which he is responsible; and will:

- Coordinate the process teams, who monitor and control the installations,
- Define the operating instruction allot tasks
- Supervise the laboratory, define the program of analysis, and interpret the results
- Draw up plant operation reports
- Inform the maintenance manager, define the modalities for work by maintenance crews.

Operating Staff

- Monitoring, reading and analysing all the operating parameters
- Applying the standardized procedures defined by Management
- Supervising and running the various units in accordance with the operating instructions, in compliance with the treatment objective
- Keeping a log of events in the installation
- Locking units out for servicing operations
- Informing operations Manager any problem in operation of equipment.

13.4.5 **Desalination Plant**

a) Operation and maintenance of all the desalination process facilities from Intake system to clear water reservoir and sludge treatment to wastewater discharge to sea through outfall diffusers.
b) The plant shall be operated continuously with plant availability at fully capacity at 98% of the time in a year.
c) Providing required manpower for routine operation of water and sludge treatment units, clear water reservoir and distribution pumps, HV/LV switchgear room, PLC control, all motors, valves and piping in the system, and laboratory.
d) Maintaining the PLC, including the hardware, software and all instruments, in good working condition. The downtime of entire control system shall not exceed 2 hours. During the downtime, the Contractor shall continue to operate the desalination plant in manual mode using the local panel controls and the readings from local instruments

e) Routine and periodic maintenance of the entire control system and instruments as per the manufacturer's recommendations.
f) Replacement of damaged controls, communication cables and power supply cables.
g) Repair or replacement, as required, of all instruments such as flow meters, pressure transmitters, pressure gauges, level sensors/transmitters, float type level switches, on-line pH meters, on-line turbidity meters, on-line residual chlorine meters and laboratory instruments along with all other equipment. The downtime of any individual instrument as referred above shall not exceed 24 hours.
h) Periodic site calibration of all measuring/metering equipment or as recommended by the manufacturer. The calibration at manufacturer's works shall be done only in case of major failure/ repairs of the instruments.
i) Preparation and submission of daily and monthly customized reports produced by the local SCADA/DCS system.
j) Provision and maintenance of all consumables for printing without any additional costs to the Employer.
k) Weekly lubrication of all gears of reduction motors, motorized valves, gates and other parts of the system.
l) Periodic operating and checking all valves and gates for their manual and electric operation. Operation of valves must be checked from local control console, switchgear and through PLC system. Any defect observed must be made good.
m) Ensuring environmentally friendly disposal of sludge at approved site(s), within a radius of 60 kilometers from the plant.
n) Operation and maintenance of all circuits and buildings associated with the treatment works.
o) Breakdown maintenance of all electrical, mechanical and instrumentation equipment.
p) Routine monitoring of substation equipment and take preventive measures (as required)
q) Routine maintenance works of lighting and earthing system.
r) Re-painting of the exposed mild steel components of pipeline, ladders, railings etc. in the desalination plant in every 3rd year of Operation and Maintenance to keep them in good shape.
s) Maintaining the surrounding areas of the filter plant free from shrubs, weeds, grass and other unwanted vegetation.
t) Annual cleaning and disinfection of the clear water reservoirs. The raw water shall be used for watering plant and washing.
u) Providing safety accessories, (e. g. gloves, shoes, first aid box, etc.)
v) Ensuring fire and safety equipment.
w) The Contractor shall provide necessary chemicals such as chlorine, acid, ferric chloride, polyelectrolytes, RO operational and cleaning chemicals, post treatment chemicals etc. The Contractor shall take three quotations from reputed suppliers of required consumables and procure the material from the lowest quoted rate supplier. The Employer will reimburse the cost of actual chemicals consumption within the guaranteed limit. Minimum 30 days chemical stock shall have to be maintained to ensure that operation is not affected and quality of water does not suffer. The Contractor shall use chemicals to ensure their most economic consumption and minimize wastage. The

maximum consumption of chemicals shall not in any way be more than the projected consumption provided by the Contractor in the Tender document. In case of increase in consumption, the difference in cost of chemicals shall not be payable to the Contractor, if the chemicals are supplied by the Contractor. If chemicals are supplied by the Employer, the difference in cost shall be recovered from the monthly payment due to the Contractor or paid by the Contractor to the Employer at the interest rate agreed by the Employer.

x) The power consumption shall also not be more than the projected consumption provided by the Contractor in the Tender. In case of increase in consumption, the difference in cost shall be recovered from the monthly payment due to the Contractor or paid by the Contractor to the Employer at the interest rate agreed by the Engineer and as indicated in the Tender Data.

13.4.6 Lubrication

The Contractor shall furnish a complete schedule of recommended oils and other lubricants in the Operation and Maintenance manual. The number of types of lubricants shall be kept to a minimum. In case of grease lubricated bearings for electric motors, lithium base grease is preferred.

The Contractor shall indicate the brand name of indigenously available equivalent lubricants, with their complete duty specifications, in the Operation and Maintenance manual. The Contractor shall also furnish the schedule of quantities for each fill, frequency of filling and annual requirement in Operation and Maintenance manual.

Where lubrication is effected by means of grease, preference shall be given to a pressure system which does not require frequent adjustment or recharging. Frequent, for this purpose, means more than once in a month. Where more than one type of special grease is required, a grease gun for each special type shall be used. All lubricant systems shall be designed so as not to cause a fire or pollution hazard.

The Contractor shall supply flushing oil for such lubrication system when an item of plant is ready for preliminary running.

13.4.7 Spare Parts

All spare parts required for the maintenance of the plant must be from the manufacturer of the equipment or, if the equipment itself has been made with parts from other manufacturers, the parts must be of the same make as used in the equipment supplied and installed.

All spare parts shall be packed for long storage under the climatic conditions prevailing at the Site. Each spare part shall be labelled on the outside of its packing with its description, number and purpose. If more than one spare is packed in a single case, a general description of the case contents shall be shown on the outside and a packing list enclosed.

13.4.8 Desalination and Ancillary Works

a) Providing guards in the campus areas round the clock, gardeners and other manpower to maintain the campus area green, neat and tidy.

b) Maintenance of gardens and plantations in campus area, which will generally involve the following activities:

1. Watering of plants at required intervals
2. Re-plantation without any additional cost in place of dead plants or damaged plants
3. Hoeing and weeding, etc.
4. Pruning, trimming and cutting of old big trees
5. Removing shrubs, weeds, grass and unwanted vegetation after each rainy season from the desalination plant area

c) Maintenance of roads and lighting fixtures and lighting circuits in the desalination plant campus.

d) Maintenance of lighting fixtures and lighting circuits, water supply facilities in the desalination plant campus, offices and other residential buildings.

e) The Contractor shall carry out ordinary repairs to buildings during the Operation and Maintenance period. The repairs may include but not limited to the following items:

- Easing of doors and windows, monsoon repairs to roofs, attention to drains, rain water spouts, attention to plinth protection.
- External white or colour wash, external or internal painting, internal distempering, renewal of approach roads within the campus.

- The frequency of repairs must not be less than as specified in Table 7:

Table 7: Repair Frequency of Buildings

S. No.	Nature of Repair	Frequency of repair for Residential Buildings	Frequency of repair for other Buildings
1	External finishing (colour washing) after attending minor repairs such as damage to plaster etc.	In 3rd year of Operation and Maintenance	Every three years
2	Internal finishing (distemper / painting) after attending minor repairs such as damage to plaster etc	In 3rd year of Operation and Maintenance	In 3rd year of Operation and Maintenance

f) Repairs to buildings must be carried out during May to June except for white and colour washing work, which should be done in September and October after monsoon in residential buildings.

g) Following repairs prior to onset of monsoon are essential:

- Any faults in the electric installation, leakages, earthing, exposed wire ends and any hazards on this account to the users/inmates of the buildings, should be taken care of suitably, wiring, which is damaged or outlived, should be replaced.
- Damaged sanitary lines should be replaced and choked lines cleared.
- Proper drainage of the area around the building should be ensured to avoid stagnation of rain water/house effluent, in order to prevent malarial conditions. Where courtyards exist in the buildings, their drainage into the outer drains should be ensured. Any choked drains should be cleared properly.
- Leaking roofs should be attended to immediately with suitable repairs/treatment, as the case may be. The rain waterspouts should also be cleared of blockages, etc. The roof should be swept clean of leaves, debris, etc. , if any.
- The plaster on outer walls of the building, which is exposed to weather, should be repaired before rains in order to prevent dampness inside. Where plinth protection has been provided, it should be checked and the damaged portions, if any, should be repaired before rains.
- Damaged flooring should be repaired/ replaced as per requirement, in order to prevent dampness inside the rooms, etc. during rains.
- Periodic repairs of damaged floors, door/window fittings, water taps, water coolers, furniture, desert coolers, electric circuits, must be taken up on complaints using the material of same quality as used during construction.

13.4.9 **Restoration of Rain Cuts**

Earthwork for restoration of rain cuts in embankment and shoulders shall be made using suitable material and compacting the same. The material used for restoration of rain cuts shall be approved by the Engineer.

The area affected by rain cuts shall be cleared of all loose soil and benched. The width of the benches shall be at least 300 mm and they shall extend continuously for a sufficient length. The height of the benches shall be in the range of 150-300 mm.

Fresh material shall be deposited in layers not exceeding 250 mm loose thickness and compacted so as to match with the benching at moisture content close to the optimum. Compaction shall be carried out using suitable equipment such as plate compactors and rammers or by suitable implements handled manually. The finished work shall conform to alignment, levels and slopes.

13.4.10 Maintenance of Earthen Shoulder

The work of maintenance of earthen shoulder shall include making up the irregularities/loss of material on shoulder to the design level by adding fresh approved soil and compacting it with appropriate equipment, or stripping excess soil from the shoulder surface, as required.

The material to be added to the shoulder, if required, shall be the selected soil as specified for shoulder works. Wherever extra earth is required to be added, the earthen shoulder shall be stripped and loosened to receive fresh soil. The deficiency of thickness shall be made up in layers of loose thickness not exceeding 250 mm. Water shall be added, if required, to attain the optimum moisture content and the layer compacted by 80 to 200 kN smooth wheel roller, vibratory roller, hand roller, plate vibrator or hand rammer to obtain at least 90% maximum dry density in accordance with IS: 2720 (Part 8). The finished surface shall have the specified cross slope and line in accordance with the drawing. The side shall be trimmed to the required slope with the help of grader or manual methods using hand tools.

Wherever the earth is required to be excavated from the shoulder, this shall be done either using equipment like grader or by manual means using hand tools. The resulting surface shall be uniform and have a field density of at least 90% maximum dry density obtained in accordance with IS:2720 (Part 8). If the surface is not uniformly compacted, it shall be excavated to a depth of 150 mm and the soil mixed with water if required and compacted at moisture content close to the optimum to achieve 90% of maximum density as stated above.

13.4.11 Wireless Communication System

a) Maintaining of a wireless communication system to ensure reliable and easy communication within to and from desalination plant at Perur, Chennai.

b) Replacement of batteries, faulty sets and all other non-functional equipment to ensure trouble free communication.

13.4.12 Operations and Maintenance Manual

The Operation and Maintenance manual shall establish guidelines for successful desalination plant systems operation by the plant operator. The guidelines shall also provide basic idea on how to operate the desalination plant and its pipe line so as to manage to steady water supply and the best water quality; less consumption of energy; less cost of maintenance expenses; a long life of equipment; protection against accidents and damage of system. The operators have to be well conversant with the manual and the guidelines stipulated therein.

In practice, the system operation and unit operation of each component needs to be continuously adjusted and modified depending on water demand and raw water quality.

The comprehensive manual shall be submitted before the commencement of operation and maintenance period, as specified for review and approval by the Engineer. It shall be periodically updated to incorporate the "best practices" experience gained while carrying out the Operation and Maintenance activities, broadly on the principles listed in Table 8

Table 8: Operation and Maintenance Manual

Items	Description
1. General	1) plan and design condition 2) quality & quantity of raw water 3) quality & quantity of product water 4) planned desalination capacity 5) design pressure(pipe line) 6) component of the system (item, specification, quantity, remark) 7) detail of facilities (name of facility, units, no. structure, capacity, remarks) 8) detail of mechanical & electrical (name, specification, s. no./tag no., quantity, remarks) 9) detail of pipe line route (flow diagram including valves/gates s. no. /tag no. , specification, quantity, remarks)
2. System operation (Mech./Elec.)	1) system drawings(plan view of desalination plant, hydraulic profile, flow diagram, single line diagram, electrical operation/control flow diagram, location /depth of water level sensor, flow control sensor system, others) 2) outline of main facility 3) concept of operation 4) concept of selection of facility 5) operation procedure(photograph with explanation) including operation of RO system 6) preparation before start operation 7) starting of system operation 8) during regular operation 9) emergency operation 10) Intake pipe pigging for cleaning 11) CIP and flushing of RO skids 12) back washing of sand filter system (when back wash timing schedule, back wash condition, restoring, stopping of filter for long time) 13) sludge handling system (sludge withdrawing, dewatering, chemical feeding, cleaning)
3. Component detail & full operation (Mech./Elec.)	1) outline of all components 2) concept of selection of component 3) concept of auto-manual operation

Items	Description
	4) preparation before start of operation 5) starting of operation 6) during regular operation 7) emergency operation
4. Equipment details (Mech./Elec.)	1) outline of all equipment 2) specification, dimensional drawings, performance curve, dimension of water level sensor 3) concept of selection of facility 4) preparation before start of operation 5) starting of system operation 6) during regular system operation 7) emergency system operation
5. Quality of water	1) water quality standards with the authorized certificates of water analysis
6. Maintenance work summary	1) inspection (system, facility, unit operation, others) 2) maintenance (system, facility, unit operation, others) 3) replace/repair(system, facility, unit operation, others) 4) modification(system, facility, unit operation, others) 5) troubleshooting(photograph with explanation)
7. List of data sheet/chart(for daily &/or periodic report)	1) operational schedule (including sludge control valves, filter backwash, slope plates cleaning, jar test, water analysis, sludge disposal, staffing/shift etc.) 2) operational chart (description/number of workers/ allocation) 3) calculation method of dosing of coagulant/chlorination dosage 4) instruction manual for equipment 5) record of pump operation (pressure, q, time, rotation, noise) 6) record of water quality 7) record of water quantity control 8) record of facility control (including filter backwash, sludge control valves) 9) record of equipment control (including generators, sludge collectors) 10) record of chemical inventory(coagulant/chlorine)

Items	Description
	11) record of sludge control (including dewatering, sludge handling, hopper) 12) record of material control 13) list of analytical instrumentation & reagent 14) list of accessory/spare parts 15) list of manufacture/supplier 16) list of contractor/subcontractors 17) emergency control (accident/water contamination etc) 18) list of key control
8. Safety & Health	1) acidification 2) coagulant 3) chlorination 4) electricity 5) fall protection 6) entering inside tank (lack of oxygen/being filled with gas poisoning) 7) health checkup (staff member/workers) 8) general personnel's cleaning 9) uniform 10) site cleaning 11) security control

a) Updating any changes in the procedures set out in the Operation and Maintenance manual, as deemed necessary based on any limitations observed during the maintenance period, including incorporating additional procedures for maintenance of other repairs/break downs not incorporated in the maintenance manual but faced during Operation and Maintenance period.

b) Procedures for repair of leaks/burst in different types of pipes must be provided, with supporting drawings. The Operation and Maintenance manual must be updated if any difference is observed during Operation and Maintenance period.

c) Frequency of spares used in maintenance of valves (air-valve, sluice valves and butterfly valves), expansion joints, equipment installed for surge protection and protection against corrosion must be recorded for updating the contents of the manual.

d) Records of troubleshooting points and details of events causing trouble (breakdowns) during maintenance of mixing and distribution chamber, flocculators, clarifiers, filters, RO system, limestone filters, CO_2 generator, product water tanks, clear water reservoir and distribution pumps, sludge thickener and pump houses for thickened sludge feed, thickened sludge transfer and belt filter press wash water unit and any other parts of the plant must be maintained and used for updating the contents of the manual.

e) Records of troubleshooting points and details of events causing troubles (break downs) during maintenance of pumps/motors/measuring equipment(s),/electric panel and accessories there in must be maintained and used for updating the contents of the manual.

f) Records of trouble shooting points and details of events causing trouble (breakdowns) during maintenance of 33 kV/3.3 kV/415 V sub-station, must be maintained and used for updating the contents of manual.

g) Records of Inventory used must be maintained and the relevant portion of Operation and Maintenance manual must be updated to list out the inventory requirements for maintaining the system for 240 months.

h) Records of the raw water quality, as monitored during very day of the Operation and Maintenance period, must be maintained and handed over after the expiry of Contract period. The chemical requirement in the worst conditions of operation must be identified and incorporated in the manual. Record keeping must be sufficient so as to assist in forming a relationship between the chemical dosages required for treatment with respect to the raw water input quality.

i) The provisions in the manual must incorporate every aspect of good industrial practices even if not elaborated here or in other parts of the bid document. The provisions in the approved operation and maintenance document shall be valid and binding for both the parties during operation and maintenance along with the additions and deletions made.

j) The manual so prepared must be updated after the end of every year of operation and maintenance, giving effect to the experience gained and the observations made by the Employer during the maintenance period.

k) At the time of handing over after completion of Operation and Maintenance period, all the equipment, including standby equipment, must be in good working order.

13.4.13 **Quality of Product Water**

Water will be provided within the permissible chemical and bacteriological parameters and, in general, there should be no lapse in it. The product water will be checked for important parameters at the critical points as mentioned in the Part-2, A-3 and A-9 - instrumentation and control documents. The product water must meet the quality and quantity as specified in bid documents Part-2 A-1 Project requirements. In case the permissible parameters are not achieved:

a) In case of lapses in more than two occasions in a calendar month, liquidated damages shall be applied at the rate of 0.5% of the Contractor's monthly charges for Operation and Maintenance for each lapse case per day as specified in Contract Data.
b) In case there are lapses in two consecutive days, liquidated damages shall be applied at the rate of 1.5% of the Contractor's monthly charges for Operation and Maintenance.

c) In case the Contractor has continuous lapses beyond two days, liquidated damages shall be applied at the rate of 5.0% of the Contractor's monthly charges for Operation and Maintenance for each day of lapse. In such case, the Contractor will be notified and the Employer will have the option of making the necessary inputs to control and improve the supply. All costs for such improvement, including 10% for overhead and administration, shall be charged to the Contractor, along with the penalty for the lapses.

13.4.14 **Facilities to Contractor**

The Contractor will be permitted to use the premises developed under the Contract for use by his staff during the operation and maintenance period to the extent agreed and approved by the Engineer.

13.4.15 **Format**

Suggested formats to be followed for proper recording of pumping and plant operations are given below. The format can be finalized during execution stage. The format is an example for format only as it does not include complete parameters.

Format 1

Daily Report on Operation and Maintenance

Prepared by: **[Name of Contractor]** Report For: **[Date]**

A. Consumption Records						
Sr. No.	Item Consumed	Meter Reading or other records		Daily Quantity	Average per m^3 of raw water	Remarks
		At 6:00 hrs of reporting day	At 6:00 hrs of previous day			
A.1	Raw seawater quantity received at plant inlet					
A.2	Coagulant					
A.3	Liquid Polymer					
A.4	Chlorine gas					
A.5	Electrical Power					

B. Quality Records							
Raw Water							
		6:00 hrs	12:00 hrs	18:00 hrs	24:00 hrs	Average	Remarks
B.1	Turbidity						
B.2	Temperature						
B.3	pH						
		Weekly Once at 12. 00 hrs					
B.4	BOD						
B.5	Colour						
B.6	SS						
B.7	Ammonia						
B.8	NO3						
Distribution Clear Water							
		6:00 hrs	12:00 hrs	18:00 hrs	24:00 hrs	Ave.	
B.9	Res. chlorine						
B.10	Turbidity						
B.11	pH						

		Daily Once at 12. 00 hrs	
B.12	SS		
B.13	Colour		
B.14	Turbidity		
		Weekly Once at 12. 00 hrs	
B.15	BOD		
B.16	NO3		
B.17	Ammonia		

C. Operational Downtime

Sr. No.	Unit	From hrs.	To hrs.	Total time	Remarks
C.1	Unit (identify)				

Signed by: ________________________________ Designation: ____________________________

On behalf of Contractor: ___________________________

Format 2

Monthly Report on Operation and Maintenance

Prepared by: **[Name of Contractor]** Report For: **[Month]**

Sr. No.	Item Consumed	Reading on last date of month	Maximum Reading of month	Average Quantity per day	Remarks
A.1	Raw seawater quantity received at plant inlet				
A.2	Liquid Polymer –1				
A.3	Liquid Polymer –2				
A.4	Chlorine gas				
A.5	Electrical Power				

B. Quality Records

Particulars		Average during month	Maximum during month	Minimum during month	Remarks
Raw Water					
B.1	Turbidity				
B.2	Temperature				
B.3	pH				
B.4	BOD				
B. 5	SS				
B.6	Colour				
	Distribution Clear Water				
B. 13	Residual chlorine				
B. 14	Turbidity				
B. 15	pH				
B. 16	Colour				
B. 16	BOD				
B. 17	SS				
B. 18	NO3				
B. 19	Ammonia				

C. Quantity of Sludge (by storage measurement)				
	Total during month	Average daily	Average per MLD of product water	Remark
Thickener				

Thickened Sludge (%)	
Belt Filter Press Solids (%)	

D. Operational Downtime				
Sr. No.	Unit	Total time during month	Average daily	Remark
D.1				

Signed by: ______________________________ Designation: __________________________

On behalf of Contractor: _________________________

13.5 Operation and Maintenance Practices for Instrumentation Control and Automation

13.5.1 General

A comprehensive maintenance program is critical to attaining long-term reliable performance of SCADA/DCS systems. Periodic device calibration, preventive maintenance, and testing allow potential problems to be identified before they can cause failure. Prompt corrective maintenance assures reliability by minimizing downtime of redundant components. The EPC or Turnkey contractor has to enter in to AMC contracts with system/equipment suppliers, as necessary. It is mandatory to enter into an agreement for minimum 5 years maintenance contract with the instrumentation, PLC and SCADA/DCS system supplier or the authorized system integrator, whosoever has executed the work for this project.

13.5.2 Preventive Maintenance

The SCADA/DCS system shall be included in the preventive maintenance (PM) program for the facility. The table below provides a list of recommended maintenance activities and frequencies for SCADA systems and their components. Preventive maintenance schedules for SCADA components and subsystems should be coordinated with those for the mechanical/electrical systems they serve to minimize overall scheduled down time.

Activity	**Frequency**
Pneumatic Systems/Components/Instruments	

Activity	Frequency
Check Regulators and Filters	Monthly
Inspect Tubing and Piping	Monthly
Actuate Pressure Switches	3 months
Calibrate Switches and Sensors	Yearly
Calibrate Pressure Gauges	Yearly
Calibrate Level Transmitters	Yearly
Calibrate Flow Transmitters	Yearly
Calibrate Pressure Transmitters	Yearly
Calibrate Thermometers/Temperature transmitters	Yearly
Calibrate Analytical Instruments/Online Instruments (pH, Turbidity Residual chlorine, etc.)	6 Months
Change Sampling solution of Analytical Instruments	As required
Electronic Systems	
Lamp Test/Verify Indicators	Monthly
Inspect Enclosures for Dirt, Water, Heat	Monthly
Run PLC Diagnostics	3 Months
Calibrate Sensors and Transmitters	Yearly
Calibrate Meters	Yearly
PLC Communication Modules	Monthly
PLC Batteries	Yearly
Test Automatic control Sequences	Monthly
Verify Alarms	Weekly
Software Maintenance and Patching	3months
Anti-virus Definition Updates	Monthly
Inspect Wire, Cable and Connections	Monthly
Inter site Communication Network	Weekly
Dead Bus Relays	3 Months
UPS setting with SCADA	Weekly
PLC Redundant Power back up	Monthly
SCADA Redundancy	Monthly

Activity	Frequency
Network Redundancy	Weekly
PLC Hot-Standby	Monthly
Historian Package(Capacity)	Monthly
Data Archiving	Monthly

Many components of SCADA systems, such as dead-bus relays, are not required to function under normal system operating modes. For this reason the system should be tested periodically under actual or simulated contingency conditions. These tests should approach as closely as possible the actual off- normal conditions in which the system must operate. For example, SCADA for Dual Redundant system should be tested by interrupting the utility source as far upstream of the normal service as possible.

Periodic system testing procedures can duplicate or be derived from the functional performance testing procedures.

The SCADA software maintenance should include timely updates of any new versions from the supplier and testing to verify proper installation on the SCADA computer. In addition, software antivirus updates should be maintained. This should be performed any time after the computer is connected to the Internet or the antivirus patch should be downloaded as and when the updates are available. Normal operation requires that the SCADA computer not be connected to the Internet.

Faulty Instruments, sensors, transmitters, communication modules, computer hardware should be replaced with new components. Repair of the failure items would not be accepted. Instruments, modules would have to replace with a new instruments and components.

13.5.3 **Concurrent Maintenance**

Concurrent maintenance is defined as testing, troubleshooting, repair or replacement of a component or subsystem while redundant component(s) or subsystem(s) are serving the load. The ability to perform concurrent maintenance is critical to attaining the specified reliability/availability criteria for facilities and must be designed into the SCADA system. Where SCADA components are associated with equipment that has redundancy and therefore are not themselves redundant, their maintenance should be scheduled to occur during maintenance of the associated equipment. SCADA components and controllers that are redundant must be capable of being taken out of service, repaired or replaced and tested without interfering with the operation of the redundant component.

13.5.4 **Reliability Centred Maintenance**

Reliability-Centred Maintenance (RCM) is an approach for developing an effective and efficient maintenance program based on the reliability characteristics of the constituent parts and subsystems, economics, and safety. RCM provides a logical, structured framework for determining the optimum mix of applicable and effective maintenance activities needed to sustain the operational reliability of systems and equipment while ensuring their safe and economical operation and support.

A significant byproduct of the application of SCADA systems to the control of facilities is the large amount of operational data made available through the trending and data storage features of the SCADA. This operational data can be used for automated performance monitoring of mechanical and electrical systems that can support a RCM approach

13.5.5 Operation and Maintenance Documentation

The contractor should perform an Operation and Maintenance analysis to determine the Operation and Maintenance data required to support maintenance of the SCADA system. This analysis should be coordinated with CMWSSB to determine maintenance parameters and Operation and Maintenance data that are available. Typical Operation and Maintenance data requirements include the following items:

- System documentation as defined in FDS, FAT & SAT documents
- Minimum spare parts list.
- Recommended spare parts list.
- Recommended onsite test equipment.
- Recommended Operation and Maintenance training.
- Recommended Operation and Maintenance to be performed by contractor

13.5.6 Spare Parts Stocking

An adequate on-site stock of spare parts is essential to obtaining high availability of ICA systems. All spare parts used for the equipment in the maintenance of the system must be from the manufacturer of the equipment or, if the equipment itself has been made with parts from other manufacturers, the parts must be of the same make as used in the equipment supplied and installed.

All spare parts shall be packed for long storage under the climatic conditions prevailing at the Site. Each spare part shall be labelled on the outside of its packing with its description, number and purpose and, if more than one spare is packed in a single case, a general description of the case contents shall be shown on the outside and a packing list enclosed.

a) Minimum recommended stocking levels include the following. These quantities may need to be increased for components which are used in large numbers in the facility:
    - Manufacturer's recommended spare parts list.
    - One each of all line replaceable boards or modules.
    - Six each power and control fuses used in the system.
    - Tools required to terminate coaxial or fibre optic cables.
b) Automation:
    - Laptop computer loaded with software required to access controllers. Licenses for all software installed on the system.

- Permission to modify program code.
- Spare cables for connecting computer to controllers.
- PLC CPU, Power supply module. 1 DI, DO, AI, AO modules, Communication module, protocol converter, etc. .
- PLC batteries, fuses, etc.

13.5.7 Utilities & Consumables

The Contractor shall provide consumables for printers e.g. : Ink cartridges (colour & B/W), A4, A3, A1 size of paper, dot-matrix print paper for the complete operation and maintenance period of 3 years. Downtime of the above system should not exceed more than 2 hours.

13.5.8 Technical Support

The Contractor should specify functional areas of the operating system and/or equipment where a Technical representative will be furnished by the manufacturer for training, test, checkout, validation, or pre-operational exercises.

Ongoing operation and maintenance of SCADA system software may require technical support from the system vendor or from agency technical personnel not located at the facility. Commercial SCADA software typically has provisions for remote modem access that permit this type of support from the vendor's location or an agency central engineering group.

Such remote access provisions represent a vulnerability to "hacking" and must be used with great caution. They should be monitored when in use and physically disconnected when not in use. Password protection policies for all SCADA systems, including PLC's, shall be in compliance with Established policies and to be agreed with the Employer's representative.

These policies require that the default password that came from the control supplier be changed when placed into operation at the facility.

14. HAND OVER

14.1 General

This section applies to procedures for transfer of the 400 MLD desalination plant at Perur, Chennai after 20 years of operation and maintenance by the Contractor. The specifications of the Plant is the complete plant including seawater pre-treatment, RO desalination and post treatment processes with sludge treatment facilities, the instrumentation and control system, the communication system, 33 kV/3.3 kV/415 V substations, DCS systems, all ancillary buildings and campus area. The procedure for Hand Over shall be processed through the final examination by the Engineer. A Completion Hand Over Certificate shall be issued after the submission of all the approved completion documents before the Contract deadline and the successful final examination.

14.2 Duties and Responsibilities

All costs for the examination/test/training, and preparation of any documents shall be the Contractor's responsibility.

14.2.1 Official Certificate

All test certificates will be issued by authorized organization by the qualified personnel with his signature.

14.2.2 Receiving Inspection

All equipment and construction material that arrive at the Site will be inspected by the Engineer to verify whether damaged or not. Rejected items shall be replaced by the Contractor at his own cost. The typical examination shall consist of as follows:

- Appearance test/visual examination
- Check attached invoice

14.2.3 Conduct First Training

The Contractor shall provide the first training program to Perur plant staff member for six months before conducting joint inspection. The typical training program is as follows:

- Basic process engineering
- Study of Operation and Maintenance manual
- Operation skill/technology (mechanical and electrical) including normal and emergency operation
- Maintenance and repair skill/technology (mechanical and electrical)
- Water analysis
- Record keeping and maintenance of records
- SCADA/DCS systems
- Safety & Health

- Visits to existing water treatment plants
- Evaluation of the program (examination)
- Others requested by the Engineer

14.2.4 **Joint Completion Inspection**

To verify the plant condition and its performance before the completion of 20 years of operation and maintenance, joint inspection will be carried out using updated Operation and Maintenance manual. Not less than two years prior to the expiry date of the O&M period, a joint inspection of the Works shall be conducted. Within 28 days of the completion of the joint inspection, the Contractor shall submit a report on the condition of the Works identifying maintenance works, replacements andother works required to be carried out to satisfy the requirements of the O&M plan after the Contract Completion Date.

The Contractor shall submit a programme for carrying out such works over the remainder of the O&M period.

The typical inspection items are shown in Table 1.

Table 1: Typical Items to be examined at the end of the Operation Service Period

Item	Description
1. Appearance test /Visual examination (Damage/crack, differential settlement, soil settlement, peel off painting, missing/lost, leakage of water/solution/gas, corrosion, decolonization, condition of maintenance, others)	• All civil structures, building including interior/exterior, fence/gate, stairs, others • All mechanical & electrical equipment/accessories, others • All pipe line valves and gates, others • All instrumentation and control equipment, others • All water quality analysers, others
2. Performance examination (Selection of operation mode, selection of facilities, flow/water level, overflow, leakage of water/solution/gas, heating, vibration/noise level, speed of rotation, smoothness, gap/spaces, accuracy, setting value, condition of maintenance, others)	• Check sequence, or manual operation including water level sensors/protections, others • Check specification of all processes facilities, others • Check specification of all mechanical equipment including pressure gauges, pressure relief valves, others • Check specification of all electrical equipment, others • Check specification of all pipe line including valves, gates, others • Check specification of all accrual condition after

Item	Description
	troubleshooting, others • Check performance (flow, pressure, noise, vibration, other conditions etc.) of all equipment and units.
3. Verification of rectified works (System, leakage, crack, damage, soil settlement, corrosion, others)	• Checklist of all defect items, history, tendency, repeating, others • Checklist of all miss operation and maintenance items, others • Check all factors of defect/miss operation, others • Verification of action on the take measures, others • Verification of all rectified works with the reports and photo, others • Check emergency works and its factor, action plan, others • Check actual condition after rectified works, others
4. Operation skill (Staff member, others)	• Review of daily report and summery reports on Operation and Maintenance activities • Check time and motion of staff member, others • Interview operator regarding troubleshooting, others • Paper test (basic knowledge, calculation of chemical dosing, safety, others) • Field test (using/put on the safety gear, drill of chlorine leakage accident, others)
5. Water analysis (Sampling and analysis, others)	• Location of sampling and time, and date • Raw water and treated water • Process wise • Authorized certificate
6. Spare parts and others	• Check inventory list (parts, chemical, reagent, others) • Check the quantity of inventory, others • Check maintenance tools and equipment, vehicles, others

14.2.5 Tests Prior to Contract Completion

Upon satisfactory completion of the items identified above, the Employer's representative shall instruct the Contractor to commence the Tests Prior to Contract Completion.

14.2.6 Submission of Completion Documents

The Contractor shall submit the completion documents after passing the final examination before the Contract deadline. The typical report consists of relevant documents for request for issue the Completion Certificate of 20 years Operation and Maintenance period. Typical completion documents are is shown in Table 2. These data shall be provided in soft and hard copies in proper professional format.

Table 2: Typical Completion Documents to be Handed Over at the End of the Operation and Maintenance Period

Contents	Description
1. Outline	Outline • Summary of project, scope of work, location of project, main component with specification, others
2. Completion Photographs (At acceptance complete inspection, completion inspection and final inspection)	Photographs with short description • Civil (structural, buildings, others) • Mechanical and Electrical (equipment, facility, others) • Piping works
3. Inspection summary (At acceptance complete inspection, completion inspection and final inspection)	Appearance test/visual/performance examination • Table of summary of daily and monthly test activities • List of type of test , date, inspector, evaluation, comments • Civil (name of structure, drawing No., drawings, design dimension, previous dimension, actual dimension, photograph with short description others) • Mechanical (name of facility and equipment, Tag. No., quantity, others) • Electrical (name of facility and equipment, Tag. No., quantity, others)
4. Main inspection data during construction	Summary of data with graphic /chart • Civil (plate load bearing test, compressive strength test, water retaining test, compaction field test, road restoration works, road construction works, hydrostatic test, others) • Mechanical (disinfection test, control of filter and

Contents	Description
	filter media quality others) • Electrical (earthing resistance test, others)
5. Inspection record (At acceptance complete inspection, completion inspection and final inspection)	• Appearance test /visual/ performance examination • Performance examination • Verification of rectified works (refer Table 15.1) • Civil • Mechanical • Electrical
6. Training and commissioning record (At first and second training program)	• Summary (schedule of training and commissioning, attendance rate, impression on training program) • Training attendance list (participants, trainings date, others) • Commissioning daily record (water flow rate of designed and actual, tested water flow, name of operated facility, list of measurement and its time and reading value, raw and treated water quality, value of V/Am/kW of each equipment, others • Photographs with short description
7. Water quality certification data (At acceptance complete inspection, completion inspection and final inspection)	• Location of sampling and time, and date • Raw water and treated water • Each process (Refer to Section 14.5, Table 14.3) • Issued from Authorized certificate
8. Operation/maintenance manual (Civil, mechanical, electrical)	Update • Refer to Section 14.5.12
9. Spare parts list	• Mechanical (name of parts, Tag. No., quantity, location of stock, others) • Electrical (name of parts, Tag. No., quantity, location of stock others) • Pipe & fittings (name of parts, Tag. No., quantity, location of stock others) • Valve & gates (name of parts, Tag. No., quantity, location of stock others) • Others (name of parts, Tag. No., quantity, location of stock others)

Contents	Description
10. Key list with boxes	• Name of key, location, Tag. No., quantity
11. Manufacture produced catalogue (Civil, mechanical, electrical)	• Civil (all related material: sand filter media, bar, round bar, cement, cement paste, asphalt, chemical admixture, water reducing agent, pozzolan, vibrator, water-tightness sheet, construction equipment, manhole, fence-gate, pipe, water-resistant coating, paint, coating agent, windows, door, lock & key, others) • Mechanical (all related equipment; pumps, fine screens, manual screen, mixer, blower, control valve, sludge collectors, dewatering, conveyor, hopper, tanks, chorine dosing equipment, coagulant dosing equipment, safety equipment, pipe, valve, gate , pressure gauge, safety valves, flow meter, coating painting, others) • Electrical (all related equipment: electric wire, electric conduit, manhole , motor, control panel, relay, transformer, heater, generator and silencer, timer, breaker, light/lamp, switch, street light, earthing, measurement equipment, air condition, communication equipment, electric pole, coating painting, ventilation fan, air duct, others) • Safety equipment • Others
12. Instruction manual (Civil, mechanical, electrical)	See above
13. Factory inspection record or quality assurance (Civil, mechanical, electrical)	• Civil (all related material : sand filter media, bar, round bar, cement, aggregate, sand, gravel, asphalt, crashed stone, chemical admixture, water reducing agent, pozzolan, water-tightness sheet, construction equipment, manhole, pipe, water-resistant coating, paint, windows, door, others) • Mechanical (all related equipment; pumps, fine screens, manual screen, mixer, blower, control valve, sludge collectors, dewatering, conveyor, hopper, tanks, chorine dosing, , safety equipment, pipe, valve, gate , pressure gauge, safety valves, flow meter, coating painting, others) • Electrical (all related equipment: electric wire, electric

Contents	Description
	conduit, manhole , motor, control panel, relay, transformer, heater, generator and silencer, timer, breaker, light/lamp, switch, street light, earthing, measurement equipment, air condition, communication equipment, electric pole, coating painting, ventilation fan, air duct, others) • Safety equipment • Others
14. Photograph (during Construction, at joint completion inspection, at defect liability) (Civil, mechanical, electrical)	History of construction Replacement of defect liability • Civil: construction site before starting construction, earthwork, , arrangement of bar, rust, cleaning before placing, formwork, concrete mixing work, placing, violator, curing, remove of formwork, backfill, compaction, all field inspection and lab test, others • Mechanical: inspection at factory, receiving inspection, completion inspection, all field inspection and lab test, others • Electrical: inspection at factory, receiving inspection, completion inspection, all field inspection and lab test, others
15. Production samples (Civil, mechanical, electrical)	All samples for technical approve • Attach Tag. No., and its name, approved sign of the Engineer.
16. Report	• Monthly and annual report • Others

14.3 Specifications

The specification of materials used for repairs shall be the same as have been used in the original work. Specifications for any materials which were not employed during construction, should be approved by the Engineer before use for repair work prior to the Hand Over. In spite of being restricted by this clause, in an emergency the Contractor may use an appropriate material for repairs even if material required for such repairs has not been approved by the Engineer. However, subsequent to the use of such material, the Contractor shall submit proposals for the approval of specifications of such materials at the earliest within two week time duration.

14.4 Check List of Contractor's Responsibility

14.4.1 General

Within the framework of the Contractor's responsibilities, the Contractor shall carry out the following activities. However, these shall not limit the requirement for other activities which otherwise are required as per terms and conditions of the Contract or to fulfil the Contractor's responsibilities or are essential as per the good industry practices. The Contractor shall hand over the components of Works in good working condition for, but not limited to the following items:

a) All process units in good working condition with replaced wear and tear parts to the satisfaction of the Engineer. All MS equipment and structures shall be buffed, cleaned and painted with the appropriate paint and of the specified specifications.

b) All civil works intact without any evidence of crack, peeling of plaster or surface finish. All civil building shall be painted with the appropriate paint and of the specified specifications.

c) All electrical equipment such as 33 kV/3.3 kV/415 V transformers, LT switchgear/MCCs, control stations, cables, earthing, AMF Panel, battery, etc. at the water treatment plant, etc. (all works constructed under this Contract) in neat and clean condition.

d) All consumables required for functioning of the plant with inventory of materials.

e) AMC contracts with system/equipment suppliers, as necessary for PLC and SCADA system supplier or the authorized system integrator as executed the work for this project.

f) Lighting fixtures and the lighting system of all areas and replacement of all non-functional lighting fixtures.

g) Records for:

- Repair history of all mechanical, electrical and instrumentation control equipment in water treatment plant, and communication instruments
- Logbooks through PLC system
- Daily log of operations of all the important equipment such as mixing and distribution chamber, chemical feed system, flocculators, clarifiers, filters, chlorination systems, electrically actuated valves, etc., with time tag
- Hourly readings water production
    - Raw seawater and product water quality test results on turbidity, residual chlorine levels, etc
    - Daily list of alarms with time tag
    - Logbook format and the data to be included in the logbook
    - Last periodic maintenance done for all equipment/buildings of the system

h) Required spares, special tools and test equipment and adequate inventory of required accessories or equipment for repair of electrical, mechanical, instrumentation and control system for 2 years, pipe and the communication system. At the end of the Contract, the Contractor shall hand over the full spares, tools and tackles (as detailed Part-2 for Spare Parts, Accessories and Tools") as supplied with the Contract by replacing the used items with fresh supplies of the same specifications.

i) Repair of the roads, buildings and campus area utilities

j) Drinking water supply facilities at water treatment plant campus and all its units

k) Record of stores for the electrical, mechanical and instrumentation and control equipment as well as that for the chemicals, membranes, and laboratory consumables at the plant. The records shall include but shall not be limited to:

- Loading/unloading of materials received and issued for works
- Proper arrangement of material in stores to ensure its safety and easy availability
- Maintaining store areas in a neat and tidy condition
- Keeping records and accounting for the incoming materials
- Keeping records and accounting for the consumed materials

l) Structures/buildings of campus areas of treatment plant and others built in the Contract must ensure adequate cleanliness, ventilation, illumination and structural safety. In addition to this, the general hygienic standards must be in acceptable condition and adequate plantation, horticultural activities must be well maintained to give pleasant environment of the campus/buildings.

m) Updated Operation and Maintenance manual as defined in specifications for operation and maintenance works.

14.4.2 **Plant in Good Working Condition**

The Contractor shall hand over all components of the works in good working condition for the following, but not limited to:

a) All the process unit facilities from intake works to clear water tank and sludge/sewage treatment facilities including mechanical, civil, electrical works and ancillary equipment and instruments such as laboratory equipment, analysers, computer system, etc. as built.

b) PLCs, including all the hardware, software and all instruments, in good working condition.

c) Entire control system and instruments as recommended by the manufacturer.

d) Replacement of damaged controls, communication cables and power supply cables.

e) Repair or replacement, as required, of all instruments such as flow meters, pressure transmitters, pressure gauges, level sensors/transmitters, float type level switches, on-line pH meters, on-line turbidity meters, on-line residual chlorine meters and laboratory instruments along with all other equipment.

f) Calibration of all measuring/metering equipment or as recommended by the manufacturer. The calibration at manufacturer's works shall be done only in case of major failure/ repairs of the instruments.

g) Submission of daily and monthly customized reports produced by the local SCADA/DCS system in hard copy and soft copy.

h) Provision of all required consumables for printing.

i) Repair of damaged moving parts, steel structures, and the reinforced concrete structures. Repairs, cleaning and disinfection shall be done.

j) Repair or replacement of all leaking or malfunctioning ERDs and associated items.

k) Lubricate of all gears of reduction motors, motorized valves, gates and other parts of the system.

l) Check all valves and gates for their manual and electric operation. Operation of valves must be checked from local control console, switchgear and through PLC system. Any defect observed must be made good.

m) Ensuring environmentally friendly disposal of sludge at approved site(s), within a radius of 30-60 kilometers from the water treatment plant.

n) Make good all circuits and buildings all electrical, mechanical and instrumentation equipment, substation equipment, lighting, DG Set and earthing system associated with the treatment works including replacement, if any (as required).

o) Painting of the exposed mild steel components of pipeline, ladders, railings etc. in the filter must be in good shape.

p) Make good surrounding areas of the filter plant free from shrubs, weeds, grass and other unwanted vegetation.

q) Ensure safety accessories,(e.g. gloves, shoes, first aid box, etc.)

r) Ensure fire and safety equipment.

s) The Contractor shall provide necessary chemicals such as alum, chlorine and polyelectrolyte for a stock of one month period.

14.4.3 **Lubrication**

In the Operation and Maintenance manuals, the Contractor shall furnish a complete schedule of recommended oils and other lubricants. The number of types of lubricants shall be kept to a minimum. In case of grease lubricated bearings for electric motors, lithium base grease is preferred.

The Contractor shall indicate the brand name of indigenously available equivalent lubricants, with their complete duty specifications, in the Operation and Maintenance manual. The Contractor shall also furnish the schedule of quantities for each fill, frequency of filling and annual requirement in Operation and Maintenance manual. Where lubrication is effected by means of grease, preference shall be given to a pressure system which does not require frequent adjustment or recharging. Frequent, for this purpose, means more than once in a month. Where more than one type of special grease is required, a grease gun for each special type shall be used.

All lubricant systems shall be designed so as not to cause a fire or pollution hazard. The Contractor shall supply flushing oil for such lubrication system when an item of plant is ready for preliminary running.

14.4.4 Spare Parts

All spare parts used for equipment in the maintenance of the system must be from the manufacturer of the equipment or, if the equipment itself has been made with parts from other manufacturers, the parts must be of the same make as used in the equipment supplied and installed.

All spare parts shall be packed for long storage under the climatic conditions prevailing at the Site. Each spare part shall be labelled on the outside of its packing with its description, number and purpose and, if more than one spare is packed in a single case, a general description of the case contents shall be shown on the outside and a packing list enclosed.

14.4.5 Electrical System

The Contractor shall hand over the following at the end of Operation and Maintenance period:

a) Revised As built drawings based on all modifications during Operation and Maintenance period. All electrical drawings like Single Line Diagrams, Control Circuits Equipment Layout, Cable Layout, and Cable Schedules, Earthing Layouts shall be maintained and shall be handed over.

b) Details of protective relay settings and time relay settings including any changes done during the Operation and Maintenance period, details of oil changes/filtration of transformers, records of any changes made in the system during the Operation and Maintenance period, etc. shall be maintained.

c) Equipment wise maintenance record during Operation and Maintenance period, as per daily checking out/inspection and regular (every 6 months or 12 months).

d) Motor wise power consumption details and over all power consumption detail of plant. Details of IR test of all equipment like HT/LT panels, HT/LT motors, generators, transformers.

e) Switchgears and cables, etc. shall be maintained.

f) Log book showing details electrical faults that have occurred in the plant and record of corrective actions taken during Operation and Maintenance period.

g) Equipment wise technical data given by equipment supplier, documents showing Bill of Materials and Operation & Maintenance Manual (hard copy and soft copy).

h) List of mandatory spares that are to be maintained at stores and their actual availability in plant, if it is below same shall replenished.

i) Details of measurement of earth resistance, earth pit wise and overall values during the Operation and Maintenance period.

j) Details of illumination levels during the Operation and Maintenance period along with details of changes, if any effected during the Operation and Maintenance period.

14.4.6 Electrical Checks to be Done During Hand Over

a) Contractor to provide a test schedule & format to be approved by Engineer before commencing any test.

b) Checking of all electrical equipment, items etc as per bill of materials. visual checking and tracing out the circuit based on revised as built drawings.
c) Visual operational checks of all equipment & protections have to be done.
d) If transformer oil samples are not tested in last 6 months same shall done during taking over.
e) Earth resistance of individual, combined pits for substations shall be checked during Hand Over.

14.4.7 Instrumentation, Control and Automation System

The Contractor shall hand over the following documents/drawings/manuals/programs at the end of Operation and Maintenance period:

a) Revised As built drawings approved by the employer's representative based on all modifications during Operation and Maintenance period. All ICA Drawings like P&ID, system configuration diagram (PLC & DCS architecture), instrument installation drawings, instrument cable schedule, and cable layouts shall be maintained and shall be handed over.
b) Handing over document/manuals shall include on a minimum five sets of soft copies and five sets of hard copies. The hard copies shall be spiral bounded clearly indicating the version/revision submitted. All the contents shall be indexed .The contents of handing over document/manual shall be clearly legible and shall include original manufacturer's literature on a minimum, and in-corporate any changes as per site conditions.
c) Detailed drawing and manual of the PLC installed. Manual shall include the PLC series installed along with complete details on I/O modules, Ethernet switch, relay modules, and converters (if any).
d) A complete manual shall be provided which shall include operating instructions and troubleshooting techniques of the PLC and accessories installed illustrated with examples. This shall be provided along with the standard manufacturer's literature.
e) A complete manual shall be provided which shall include operating instructions and troubleshooting techniques of the DCS and accessories installed, illustrated with examples. This shall be provided along with the standard manufacturer's literature.
f) A complete manual shall be provided which shall include operating instructions and troubleshooting techniques of the ODMS installed illustrated with examples. This shall be provided along with the standard manufacturer's literature.
g) A complete manual shall be provided which shall include operating instructions and troubleshooting techniques of the interface control panel, where applicable. This shall be provided along with the standard manufacturer's literature.
h) Interoperability testing tool/software shall be provided along with relevant manuals and operating instruction with examples.
i) Latest PLC program back-up, SCADA/DCS software back-up with license, SCADA database backup, reports and alarm back-up, Historical archived data containing reports

and alarms and ODMS data and configuration set-up shall be provided.

j) All software's used under ICA shall be handed over along with their original licenses.

k) Complete list of database/addresses shall be provided clearly indicating the spare tags for PLC, SCADA and ODMS software's.

l) List of mandatory spares that are to be maintained at stores for complete ICA package and their actual availability in plant shall be provided.

m) Any password's set to access the internal PLC program; interface control panel shall be provided and demonstrated.

n) All passwords (PLC, Interface control panel & DCS and other software/hardware) shall be provided in a sealed envelope and addressed to the Engineer.

o) PLC, SCADA and ODMS package shall be updated with the latest software version/patch before handing over. The same shall demonstrated to the Engineer.

p) Latest licensed version of Windows operating system along with MS Office or equivalent software which is prevailing at that point of time shall be installed on SCADA machines and other machines installed and integrated with the SCADA and ODMS package. The same shall be demonstrated to the Engineer.

q) Contractor shall conduct a training session for the client's staff which shall include PLC configuration, trouble shooting techniques, SCADA configuration and trouble shooting techniques, ODMS configuration and trouble shooting techniques, diagnostic techniques and trouble shooting techniques for wireless technology employed for communication.

r) The training session shall be conducted for the duration indicated elsewhere in the specification documents.

s) Manufacturer's literature/manuals for flow meters, level transmitters, switches, pressure transmitters etc and analytical instruments installed.

t) Instrument wise, PLC and SCADA wise and ODMS maintenance record during complete Operation and Maintenance period shall be provided.

u) A complete and updated list of all manufacturers/system integrators/contractors of ICA with contact numbers shall be provided. The same shall also be made available on site for ready reference.

v) The latest versions of all drawings of ICA, which shall include cable termination details, I/O mapping, database details etc shall be provided in PDF format and editable format and loaded in the operator machine available on site. The same shall be demonstrated to the Engineer.

14.4.8 ICA Checks to be Done during Hand Over

a) Contractor to provide a test schedule and format to be approved by the Engineer before commencing any of the tests.

b) Functional checking of all laboratory instruments/equipment and ICA equipment including online analyzers, flow meters, pressure and level instruments, vibration monitoring instruments, and wireless equipment being used for communication.

c) Loop checks will be conducted.

d) All instrument cabling shall be inspected for continuity. If found faulty, the same shall be replaced and demonstrated.

e) All instrumentation cable conduits shall be checked for damage. If found faulty , they shall be rectified or replaced and sealed to the satisfaction of the Engineer

f) Visual operational checks of PLC panel, SCADA system and interface control panel.

g) Licensing feature of PLC, SCADA software and hardware, ODMS software and other hardware shall be demonstrated.

h) Functional check of set points change at HMI and it's downloading to PLC's concerned.

i) Hot-standby feature of PLC and hot swappable feature of I/O modules shall be demonstrated. If found to be faulty/non-operational, shall be rectified and if required replaced to normal working condition and demonstrated to the client.

j) Dual-redundant server feature of SCADA shall be demonstrated. If found to be faulty/non-operational, shall be rectified and if required replaced to normal working condition and demonstrated to the client.

k) Functional check of ODMS software in conjunction with SCADA shall be conducted.

l) Functional check of data received/transmitted from remote stations shall be conducted in conjunction with SCADA.

m) Historical archiving of all data shall be demonstrated.

n) Availability of memory for smooth operation of PLC, SCADA and ODMS machines shall be demonstrated. If found to be inadequate, the same shall be rectified/archived and demonstrated.

o) If any instruments and automation equipment are found to be faulty during the above tests, the same shall be rectified or replaced as necessary.

14.4.9 **Plant Ancillary Works**

a) Make gardens and plantation in the campus area green, neat and tidy with removal of shrubs, weeds, grass and unwanted vegetation and make pruning, trimming and cutting of old big trees from the Plant Area along with .

b) Reinstate the roads and lighting fixtures and lighting circuits in water treatment plant campus to its original state.

c) Make good and in working condition for lighting fixtures and lighting circuits, water supply facilities in water treatment plant campus, offices and other residential buildings.

d) The Contractor shall carry out ordinary repairs to buildings. The repairs shall include but not limited to the following items:

- Easing of doors and windows, monsoon repairs to roofs, attention to drains, rain water spouts, attention to plinth protection.
- External white or colour wash, external or internal painting, internal distempering, renewal of approach roads within the campus.
- Repairs to other administrative buildings must be carried out during May to June

except for white and colour washing work, which shall be done in September and October after monsoon in residential buildings. The building shall fully renovated as needed at the Hand Over.

Following repairs prior to onset of preceding monsoon are essential:

a) Any faults in the electric installation, leakages, earthing, exposed wire ends and any hazards on this account to the users/inmates of the buildings, shall be taken care of suitably, wiring, which is damaged or outlived, shall be replaced.
b) Damaged sanitary lines shall be replaced and choked lines cleared.
c) Proper drainage of the area around the building shall be ensured to avoid stagnation of rain water/house effluent, in order to prevent malarial conditions. Where courtyards exist in the buildings, their drainage into the outer drains shall be ensured. Any choked drains shall be cleared properly.
d) Leaking roofs shall be attended to immediately with suitable repairs/treatment, as the case may be. The rain waterspouts shall also be cleared of blockages, etc. The roof shall be swept clean of leaves, debris, etc., if any.
e) The plaster on outer walls of the building, which is exposed to weather, shall be repaired before rains in order to prevent dampness inside. Where plinth protection has been provided, it shall be checked and the damaged portions, if any, shall be repaired before rains.
f) Damaged flooring shall be repaired/replaced as per requirement, in order to prevent dampness inside the rooms, etc. during rains.
g) Repairs of damaged floors, door/window fittings, water taps, water coolers, furniture, desert coolers, electric circuits, must be taken up on complaints using the material of same quality as used during construction.

14.4.10 **Restoration of Rain Cuts**

Earthwork for restoration of rain cuts in embankment and shoulders shall be made using suitable material and compacting the same. The material used for restoration of rain cuts shall be approved by Engineer and in general shall be as specified for earth work in specifications elsewhere.

14.4.11 **Maintenance of Earthen Shoulder**

The work of maintenance of earthen shoulder shall include making up the irregularities/loss of material on shoulder to the design level by adding fresh approved soil and compacting it with appropriate equipment, or stripping excess soil from the shoulder surface, as required.

14.4.12 **Wireless Communication System**

Make good a wireless communication system to ensure reliable and easy communication to and from Desalination Plant at Perur, to CMWSSB, Chennai. Replacement of batteries, faulty sets and all other non-functional equipment to ensure trouble free communication, if required.

14.4.13 Operation and Maintenance Manual

The comprehensive Operation and Maintenance manual (seven sets) shall be submitted at the end of the Operation and Maintenance period as specified. It shall be updated based on the Engineer's comments. These manuals shall be made available during training sessions conducted by the Contractor. A soft copy of the same shall also be submitted.

14.4.14 Quality of Product Water

Water shall be provided within the permissible chemical and bacteriological parameters. The product water quality shall be as per BIS 10500 standards.

14.4.15 Payments

The Contractor, at the time of tendering, shall ensure the completeness and adequacy of his Tender Price to fulfil the entire responsibilities as described in specifications. His Tender Price for operation and maintenance, as quoted on a yearly basis in the Schedule of Prices, shall include all costs for Hand Over.

14.4.16 Format

For proper recording of water treatment plant operations, the formats are provided in Operation and Maintenance Specifications in Volume 2, Part 14. All the operation and maintenance records shall be submitted in hard and soft editable form.

14.5 Completion Certificate

Notwithstanding the foregoing, other services to be performed by the Contractor must be completed before the Contractor will be entitled to receive the Contract Completion Certificate. Pre-conditions which must be fulfilled by the Contractor before the Contract Completion Certificate will be issued have been discussed above and specifically are:

(a) Inspection and tests of all the Works
(b) Remedying defects found during tests and inspection;
(c) All activities in accordance with the Clause 14.4;
(d) Updating Operation and Maintenance manuals providing performance records and data; and

A joint inspection shall be arranged by the Contractor to assess the condition of civil structure, mechanical and electrical equipment and instrumentation. Based on this inspection, a list of remedial repair and replacement for the components will be prepared by the Engineer. The Contractor shall carryout such remedial works at his own cost. Again joint inspection shall be arranged by the Contractor for certification of completion of remedial work as well as condition of all civil work to its original appearance. The Contractor shall submit the entire required document to the Engineer / Employer's representative for review and comments. The Contractor shall resubmit the document incorporating any comments.

The Employer shall issue a Contract Completion Certificate to the Contractor on his request within 30 days after the take back of the plant subject to the above documents and obligation are met by the Contractor before 90 days prior to Hand Over.

ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

The Bidder shall provide his Environmental and Social Management Plan (ESMP) in detail so as to demonstrate the procedures that will be used to ensure that the environmental and social concerns and requirements.

After award of contract and before the start of work, Contractor shall review the available Environmental and Social Management Plan (ESMP) for the project available below with CMWSSB. The contractor shall duly update the ESMP to ensure compliance with all applicable legislation and regulations of State/ Central Government and also with JICA Environmental and Social guidelines. The ESMP shall incorporate the requirements stipulated in the Project's EIA Report and conditions of approval from State/ Centre Regulatory agencies. The ESMP shall also clearly define roles, responsibilities, reporting requirement and budgetary allocations for implementation of mitigation measures. The revised ESMP shall be submitted by the Contractor to CMWSSB for necessary approval before initiating any groundwork.

The ESMP shall identify the potential environmental and social impacts from the various construction and operations and maintenance activities to be undertaken in the Contract and set out in detail the approach he will adopt in mitigating these impacts to ensure that the residual impacts are minor and confined to a short period.

While preparing the proposed ESMP, the Bidder shall consider but not be limited to the following:

- The Bidder shall pay attention to the methods of materials delivery, storage, usage and disposal; equipment usage; and site activities to ensure they have minimal impact on the environment, workforce and community,
- The Bidder shall propose only environmentally safe products and practices in performing his works, and
- The Bidder shall comply with all the statutes regarding environmental and social impacts.

The Bidder shall provide separate descriptions of its proposals for minimizing any adverse environmental and social impacts/ effects during the construction phase and the subsequent operations and maintenance phase.

15. ENVIRONMENTAL MANAGEMENT PLAN

15.1 Project-related activities, issues, and mitigation measures

15.1.1 Pre-Construction Stage

S No.	Project-related Issues	Mitigation Measures to be taken	Responsibilities	
			Planning and Execution	Supervision/ Monitoring
A.	**Pre-Construction Stage**			
A.1	Assure compliance with relevant construction field legislation	All clearances required and Environmental and social aspects from other departments shall be ensured and made available before the start of work. Acquire construction permit and Provide Water management guidelines. The project requires Consent to Establish (CtE) under the Water and Air Act from the Tamil Nadu State Pollution Control Board.	CMWSSB/ Contractor	Project head/ Incharge CMWSSB
A.2	Utility Relocation	• Identify the common utilities that would be affected, such as telephone cables, electric cables, electric poles, water pipelines etc., • Affected utilities shall be relocated with prior approval of the concerned agencies before construction starts. • Alternate temporary arrangement for crossing over shall be provided.	Planning - CMWSSB Execution - Contractor	Project head/ Incharge CMWSSB
A.3	Supply of Material and resources	Procurement of construction material only from permitted sites and licensed/ authorized quarries. Identify locally available resources/ materials and eco-friendly materials.	Contractor	Project head/ Incharge CMWSSB
A.4	Water	The Contractor will be responsible for arranging an adequate supply of water of the required quantity for the entire construction period. Groundwater extraction not permitted in the area. The contractor will minimize the wastage of water during construction.	Contractor	Project head/ Incharge CMWSSB

S No.	Project-related Issues	Mitigation Measures to be taken	Responsibilities	
			Planning and Execution	Supervision/ Monitoring
A.5	Appointment of Environment Health & Safety Officer	The contractor will appoint qualified and experienced Environmental Engineer, who will dedicatedly work and ensure implementation of EMP, including Occupational health and safety issues at the camp, construction work sites.	Contractor	Project head/ Incharge CMWSSB
A.6	Other Construction Vehicles, Equipment and Machinery	All vehicles, equipment and machinery to be procured for construction/ protection work will conform to the relevant Bureau of Indian Standard (BIS) norms/ CPCB standards. The discharge standards promulgated under the Environment Protection Act, 1986 and Motor Vehicles Act, 1988 will be strictly adhered to. Soundproof DG set as per regulations will be used at the project site. The contractor will maintain records of Pollution Under Control (PUC) certificates for all vehicles used during the contract period, which will be produced to the Project Implementation Unit for verification whenever required.	Contractor	Project head/ Incharge CMWSSB
A.7	Risk Assessment and preparation of management plans[2]	Risk and hazards associated with different construction activities shall be identified by the contractor, and accordingly, management plans shall be prepared for implementation on-site such as • Construction Labour Management Plan; • Traffic Management Plan; • Health and Safety Management Plan; • Construction material Management Plan; • Air pollution control Plan;	Contractor	Project head/ Incharge CMWSSB

S No.	Project-related Issues	Mitigation Measures to be taken	Responsibilities	
			Planning and Execution	Supervision/ Monitoring
		• Construction Waste Management Plan; • Spillage Management Plan; • Marine environment Management Plan; • Tree plantation Programme; • Environmental Monitoring Plan including marine water and sediment quality monitoring; • Emergency Response Plan; and Construction Demobilization Plan.		
A.8	Disaster Management Plan[1]	The CMWSSB shall identify the key risks associated with each component/ activities for entire project life cycle (construction, operations, & decommissioning) and shall prepare Disaster Management Plan (DMP) for the proposed plant. • Further, the DMP for the plant should be synchronized with the district Disaster Management Plan (DMP) for off-site emergencies. • Contractor shall ensure the availability of required resources for the implementation of DMP at the site and incapacitate local communities in handling disaster and emergency response		Project head/ Incharge CMWSSB

S No.	Project-related Issues	Mitigation Measures to be taken	Responsibilities	
			Planning and Execution	**Supervision/ Monitoring**
A.9	Land Acquisition/ Resettlement & Rehabilitation (R&R)	R&R issue is not involved in the proposed land. However, the site has tree plantation, which needs to be cleared. These trees to be cleared in accordance with the provisions given under Government order (G.O.157) dated 29.4.2016 The plan is to be prepared for clearing the trees, i.e. cutting Schedules, coordination with the Forest Department and/ or, TN-Newsprint and Papers, Total value of the trees, Budget allocations, compensation to the landowner, auction systems and management of tree cutting for pulps, waste management, construction vehicle and equipment managements etc., for Perur DSP site.	CMWSSB/ Prospective Tree cutting contractor	Project head/ Incharge CMWSSB

[1] Required approvals and permits are also needed during operations and decommissioning phase, therefore, CMWSSB needs to ensure the required compliance

15.1.2 Construction Stage

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
B	**Construction Phase**							
B.1	Trenching for Intake and outfall pipelines	Marine water quality	Short Term, Localised, Reversible	– Increase in turbidity affecting the Photosynthetic process affecting the aquatic productivity. – Suspended Particles will affect the filter feeders, and adult fish will migrate from the site of impact – Change in marine water quality due to aqueous discharges (oily waste, sanitary	- Check turbidity levels with baseline levels as a reference during the entire monitoring programme - Use of good engineering tools like cutter suction dredger for trenching to be used - Controlled method of dredging with the latest technology which will limit the plume generation - Discharge of waste into the sea will be prohibited - Oil Spill control measures will be adopted - Ensure slop tanks will be provided to barges/ workboats for collection of liquid/ solid waste & Marine	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
				wastes) from dredgers, barges and workboats	environmental monitoring program			
		Marine ecology	Short Term Localised Reversible	– Trenching will disturb the sea bed resulting in loss of seagrass beds and associated benthic communities – Boat movement and fishing activity will be restricted – The decrease in DO levels – Increase in noise levels – Removal of benthic communities	- Silt fences (Pollution Control Equipment) are utilized for controlling turbid water during the construction of trenches for the pipelines - To complete the trenching works in the shortest duration. - Environmental education on the marine ecosystem as well as the habitat of sea turtles to workers, labourers, and surrounding villagers. - Preparation of reports of Sea turtle sightings in and around the seashore in Perur to relevant official entities and NGOs. - Avoidance of installations of intake/ outfall pipelines during the sea turtles egg-laying seasons.			

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
				– Increase in species diversity and density in areas adjoining dredging site – Smothering or blanketing of sub-tidal communities.	- Actions to be taken in cases where sea turtles are observed in and around the seashore in Perur such as to contact to relevant NGOs and official entities handling sea turtle conservations and monitoring for getting necessary instructions. - Temporary suspension of the constructions for DSP. - Announcement of the existence of sea turtles to the contractor(s), construction workers/labourers and surrounding communities.			
		Mangrove area	Long Term Localised Non-Reversible	– Impact on nearby mangrove	- No mangroves were observed at the proposed project site The impact is not envisaged	Contractor	Contractor	CMWSSB
B.2	Seawater Intake head	Entrapment of fishes and other organisms	Continuous	– Impact on Fish and Fish larvae	– Deep Water Intake having velocity cap and screen is proposed.	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
		Entrainment of smaller organisms such as fish larvae.			– The intake velocity is limited to 0.12 m/s – The bar screen of 0.1 m width is to be installed Above are the design consideration included in the project			
B.3	Fishing	Fishermen and fishing travellers	Short Term Localised Reversible	– Impact on fishing due to Construction works – During the trenching for laying the submarine pipeline, the fisherman will not be allowed to cross over the areas where trenching is being done. This is a	- Proposed construction is planned within CMWSSB areas near Approach Channel and at existing Anchorage areas where fishing activities are not permitted: however, the following measures are suggested: - Signboards will be placed at the construction site to make fishermen aware of ongoing activities - Necessary marker buoys will be installed	Contractor	CMWSSB	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
				short term impact and completely reversible as there will not be any prohibition of fisherman crossing the areas above the path where the submarine pipeline is laid	- Interactions will be initiated with a fishing community prior to commencement of construction - Construction shall be limited to as per development plan. - Proper Planning execution of offshore construction activities to ensure the completion of construction as per schedule - Ensure slop tanks will be provided to barges/ workboats for collection of liquid/ solid waste - Trenching will be done only in small stretches, and so fishing activities can continue as normal in all other areas except where the active trenching/ laying of the pipeline is being done. There will not be any prohibition of fisherman crossing the areas above the submarine pipeline are laid below the seabed.			

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
B.4	Outfall diffuser	Marine water quality	Continuous	– Increased Salinity	- Faster dilution of moderately high salinity levels to ambient levels. - Brine diffuser with high brine diffusion efficiency has been proposed. - Monitoring of marine water quality for timely action during exceedance of the specified value more than 1% increase in salinity at 400m radius from the briner diffuser position.	Contractor	Contractor	CMWSSB
		Chlorine concentration		– Chorine concentration to be maintained below 0.2 ppm at the outfall.	- Chlorine dosing rate to intake seawater is designed for the elimination of marine growth at intake and inside the pipeline. - Residual Cl2 concentration will be approximately 0.2 ppm at the outlet of the pre-treatment system by consuming Cl2 in the intake and pre-treatment processes.			

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					- To protect the RO membrane from chlorine attack, Sodium Bisulphite (SBS) is injected for removing Cl2 at the inlet of the RO membrane. Accordingly, the brine has no chlorine as calculated in the above equation. - RO reject contains an excess SMBS which can reduce the Cl2 concentration in the discharge. During regular operation, the Cl2 concentration of the discharge from DSP can be maintained less than 0.2 ppm.			
B.5	Vehicle movement	Air quality	Short Term Localised Reversible	– Negative Impact of Air quality	- Periodic inspection of exhaust gases of dump trucks, other trucks and heavy equipment to be used; - Water spraying for heavy vehicles, equipment and trucks operation on-site in the dry season to avoid dust uplift and air pollution;	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					- Trucks carrying construction material/ demolition debris to be adequately covered to avoid dust pollution and to avoid the material spillage; - The contractor shall ensure that the batching plant has closed belt conveyor; - DG set shall have adequate stack height as per TNPCB requirement; - Excavated soil shall be covered to avoid dust emissions.			
B.6	Manpower for Construction works	Water Quality	Short Term Localised Reversible	– Negative Impact of water quality	- Construction office will be provided with an adequate number of toilets as per labour laws and connected with a septic tank or modular STP for treatment of wastewater.	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					- Once the construction is over, Septic tank to be removed and closed.			
B.7	Noise and Vibration	Noise Quality	Short Term Localised s	– Negative Impact of noise quality	PPEs to be provided to all labours working at the site. - Servicing of all vehicles and machinery shall be done regularly as per the manufacturer's guidelines, and during routine servicing operations, the effectiveness of exhaust silencers will be checked and if found defective will be replaced. - Batching plant shall be located minimum 1 km away from the nearby settlement, and noise barriers shall be provided around batching plant in case of nearby settlement is located much closer to the batching plant site; - DG set shall have an acoustic enclosure.	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					- Maintenance of vehicles, equipment and machinery shall be regular and up to the satisfaction of the Engineer to keep noise levels at the minimum. - The contractor should maintain the proper records for all the constructions vehicles and have a valid fitness certificate, NOC, insurance etc. - The construction activities shall be carried out in a planned manner restricting high noise-generating construction activities only during daytime; - Acoustic measures to be provided to reduce noise propagation to noise-generating machinery during operations. - Regular monitoring shall be conducted at site during operations.			

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
B.8	Solid waste management	Soil Quality	Short Term Localised Reversible	– Impacts due to disposal of solid waste	- Periodical de-sludge activities for toilets in construction sites by the use of public services or by the service providers. - Waste oil (from hydraulic systems, etc.) collection and treatment by solid waste collection companies. Storage at DSP site to be provided with secondary containment (Dike) for avoiding any spillages. - Surplus soil management by back-filling. - Being a greenfield project, Construction waste and debris waste generation is minimal. The minor quantity generated will be utilized within the DSP for various construction works	Contractor	Contractor	CMWSSB
B.9	Handling of Hazardous Waste	Human safety and property loss	Short Term Localised	– Fire accidents due to hazardous material handling	- Hazardous materials such as lubricants, paints, compressed gases, varnishes etc., will be stored and disposed of as per the	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					Hazardous Wastes (Management, Handling) Rules 2016 India - Hazardous wastes will be disposed of through approved TNPCB/ CPCB authorised recycler/ disposal agency. Copy of the agreement should be maintained with inventories. - Regular audit of hazardous waste generated and records and records - A suitable site should be identified for the safe storage and handling of chemicals and other hazardous materials with a paved surface and proper display of requirements and marking as a protected area. - Secondary containment shall be provided for hazardous chemicals such as diesel, lubricants, paints			

Sr. No.	**Project Activity**	**Relevant Environmental components likely to be impacted**	**Nature of Impact**	**Likely Impacts and their significance in the absence of Mitigation Measures**	**Proposed Mitigation Measures**	**Responsibilities**		
						Planning	**Execution**	**Monitoring**
					etc. - Material safety data sheets (MSDS) of all the hazardous chemicals shall be properly displayed at storage areas as well as handling areas.			
B.10	Transportation of Construction material and mobilization of construction machinery and vehicular movement within site[4]			–	- Contractor shall ensure that traffic management plan for onsite and offsite vehicular movement is in place to the satisfaction of the CMWSSB Engineers; - Routes for use by construction traffic within site to be planned with proper signage to minimize encountering of construction workers with vehicles. The routes for the movement of heavy machinery shall be designated to avoid the soil compaction in other areas;	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					- All vehicles deployed at the site shall be pollution under control (PUC) certified; - Holding area shall be provided within site for vehicles waiting to deliver loads at the site so as to avoid queuing outside the site; - Proper clearance to be obtained from the concerned authorities and sent to the CMWSSB before the commencement of works; - Modern machinery such as JCBs, backhoes etc., shall be used to increase work efficiency and minimize the construction period. Regular maintenance shall be done.			
B.11	Barricading site			–	- Contractor shall ensure that the construction area is barricaded properly. - The construction site should be barricaded at all time in with	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					adequate marking, flags, reflectors etc. to isolate it from other operating areas. - Barricading the onshore pipeline route prior to construction activities.			
B.12	Site preparation-excavation and levelling			–	- Disturbance to land surface contours to be kept to a minimum. Contractor shall try to maintain the natural drainage pattern existing onsite; - Adequate drains and slopes to be laid across the proposed Project site prior to the start of excavation work to ensure adequate cross drainage.	Contractor	Contractor	CMWSSB
B.13	Top Soil Protection			–	- Topsoil removed prior to commencement of construction activities shall be stored separately, protected and reused	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					for landscape development within the project area. - Land disturbance shall be restricted to the footprint of the Project components, and the remaining area will be kept undisturbed to the extent possible. - All excavations should be closed before the start of the rainy season.			
B.14	Storage of construction material			–	- Contractor shall identify designated covered area for storage of construction material with proper marking and measures to avoid dust emissions. - Construction material stored in open shall be covered in order to avoid wind-blown dust emissions.	Contractor	Contractor	CMWSSB
B.15	Removal of temporary construction structures and demobilization			–	- Contractor to prepare site restoration plans, the plan is to be implemented by the contractor prior to demobilization.	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
	of construction machinery				- On completion of the works, all temporary structures will be cleared away, all rubbish cleared, excreta or other disposal pits or trenches filled in and effectively sealed off and the site left clean and tidy, at the contractor's expenses, - to the entire satisfaction of the engineer			
B.16	Compliance to Permits			–	- Contractor shall ensure all compliance conditions given in CRZ clearance, Consent to Establish are compiled, and compliance monitoring reports are submitted to agencies on a regular basis.	Contractor	Contractor	CMWSSB
B.17	- Chance found archaeological property	-	-	–	- All fossils, coins, articles of the value of antiquity, structures and other remains or things of geological or archaeological interest discovered on the site shall be the property of the Government	Contractor	Contractor	CMWSSB

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					and shall be dealt with as per provisions of the relevant legislation. - The contractor will take reasonable precautions to prevent his workmen or any other persons from removing and damaging any such article or thing. He will, immediately upon discovery thereof and before removal, acquaint the Engineer of such discovery and carry out the SC's instructions for dealing with the same, waiting which all work shall be stopped. - The Engineer will seek direction from the Archaeological Survey of India (ASI) before instructing the Contractor to recommence the work at the site			
C	**Operation Phase**							

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
C.1	Potable water production	Water Quality	Localised Reversible	– Impact on offshore water quality	- Periodical maintenance of Screens, Lamella, DAF, DMF, Membrane, CIP systems of DSP operation, filter backwashing, Belt filter press washing and Sewage Treatment Plant (STP) based on relevant O&M manuals and instructions of such facilities.	O&M Contractor	O&M Contractor	CMWSSB
		Noise Quality	Localised Reversible	– Due to the operation of Blowers, DG sets	- Provision of acoustic enclosures for equipment - Personal Protecting Equipment (PPE).			
		Ecosystem	Localised Reversible	–	- Chlorine from DSP shall be maintained less than 0.2 ppm at diffuser of the outfall. - Implementation of environmental education on the marine ecosystem as well as the habitat of sea turtles to workers and labourers in DSP, and surrounding villagers.			

Sr. No.	Project Activity	Relevant Environmental components likely to be impacted	Nature of Impact	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsibilities		
						Planning	Execution	Monitoring
					- Preparation of reports of Sea turtle sightings in and around the seashore in Perur to relevant official entities and NGO. - Collaboration and consultation with other plants in the vicinity for conservation activities as directed by Government authorities time-to-time.			
C.2	Compliance to Permits			–	- Contractor shall ensure all compliance conditions given in CRZ clearance, Consent to Operate is compiled, and compliance monitoring reports are submitted to agencies on a regular basis.	Contractor	Contractor	CMWSSB

The approvals and permits are also needed during operations and decommissioning phase; therefore, CMWSSB needs to ensure the required compliance.

15.2 Environmental Monitoring Plan (EMoP)

The environmental monitoring plan helps in signalling the potential problems resulting from the proposed project activities and will allow for prompt implementation of corrective measures. The environmental monitoring will be required during both construction and operational phases. The following parameters are proposed to be monitored by the Contractor.

- Terrestrial Water Quality (Groundwater and Surface water)
- Air Quality
- Noise Intensity
- Soil Quality
- Marine Water Quality
- Marine Ecological Monitoring
- Marine Sediment Quality

Environmental monitoring during the pre-construction phase is important to set up the baseline data and to predict the deviation from baseline data and adverse impacts during construction and operations phases.

Pre-construction phase baseline monitoring for all the aforesaid monitoring parameters is required to be carried out by the contractor for 3 month duration.

The results of monitoring will be required to be provided to JICA every quarter during the construction phase and biannually during the operation of the desalination plant until the two years after the completion of the project.

15.2.1 Details of Environmental Monitoring Plan

Environmental Item	Monitoring Item	Location	Frequency	Responsible Organization
Construction Phase				
Air Pollution*	· Visual inspection of discharge conditions of exhaust gases (such as black smoke) of dump trucks, other trucks and heavy equipment and maintenance of the inspection logbook.	Construction site	Daily	Contractors

Environmental Item	Monitoring Item	Location	Frequency	Responsible Organization
	· Visual inspection on soil dust diffusions in the dry season for water spraying.	Construction site	Daily (Dry Season only)	Contractors
Water Quality	· Visual inspection of sewage water leakage (overflow), bad odour, the emergence of vector flies and de-sludge activities for the on-site toilets	Construction site	Once/ month	Contractors
	· Checking Turbidity levels with baseline levels turbid water in the sea during installations of intake/outfall pipelines	Intake/ outfall installation sea areas	Daily for the installation period	Contractors
Wastes	· Waste composition, quantity, transportation and treatment methods	Construction site	Once/ month	Contractors
Soil Contamination	· Visual inspection of leakage conditions of oil and fuel leakages (from Engine, hydraulic power units and fuel tanks) of dump trucks, other trucks and heavy equipment	Construction site	Daily	Contractors
Noise and Vibration*	· Visual inspection (common	Construction site	Daily	Contractors

Environmental Item	**Monitoring Item**	**Location**	**Frequency**	**Responsible Organization**
	sensation) of silencer conditions of dump trucks, other trucks and heavy Equipment			
Ecosystem	· Visual inspection on turbid water in the sea during installations of intake/outfall pipelines	Intake/outfall installation sea areas	Daily for the installation period	Contractors
	· Implementation of environmental education on the marine ecosystem and sea turtles.	Construction site and surrounding communities	Twice/ year	Contractors/ CMWSSB
	· Information on Sea turtle sightings in and around the seashore in Perur	Construction site	In the event of Sightings	Contractors/ CMWSSB
	· Actions on sea turtle sighting (construction suspensions periods, records of the announcements and relevant entities contacted) taken by CMWSSB	Construction site and surrounding communities	In the event of Sightings	CMWSSB
Land Acquisition/ /Resettlement	· Implementation of tree cutting action plan (Per-Construction Stage)	Construction site	Once/week	Contractors/ CMWSSB
Living and Livelihood	· Checking Turbidity levels with baseline levels turbid water	Intake/ outfall installation sea areas	Daily for the	Contractors

Environmental Item	**Monitoring Item**	**Location**	**Frequency**	**Responsible Organization**
	in the sea during installations of intake/ outfall pipelines		installation period	
	· Pipelines installation schedules · Installation (Construction) Management			
Social Infrastructure and Services	· Implementation of construction vehicle management plans	Construction site	Daily	Contractors
	· Implementation of meetings with communities	Construction site and surrounding communities	Where necessary	CMWSSB/ Contractors
Risk of infectious diseases such as HIV/ AIDS	· Implementation of Health and Sanitation education on STD.	Construction site and surrounding communities	Once/ year	
Working Conditions/ Work Safety	Visual inspection on the utilization of PPE by workers/labours	Construction site	Daily	CMWSSB/ Contractors
Accidents	Implementation of Traffic safety education	Construction site and surrounding Communities	Once/ year	CMWSSB/ Contractors
General Environment#	Site conditions	Construction site and the coast	Every year	CMWSSB
Operational Phase				
Water Quality	Water quality of Raw seawater and Potable water in DSP	DSP	Daily	DSP Operator

Environmental Item	Monitoring Item	Location	Frequency	Responsible Organization
	Concentration of Brine diffusion	Seawater at the nearest beach	Daily	DSP Operator
	· Visual inspection of sewage leakage (overflow), bad odour, the emergence of vector flies of Sewage Treatment Plant (STP)	DSP	Once/month	DSP Operator
	· Operational Inspection in accordance with instructions on the STP as suggested by the STP construction sub-contractor including Inlet and outlet quantity and quality monitoring	DSP	Daily	DSP Operator
Ecosystem	· Implementation of Meetings on environmental education.	DSP and surrounding communities	Once/ year	DSP Operator/ CMWSSB
	· Information on Sea turtle sightings in and around the seashore of Perur	DSP and surrounding communities	In the event of Sightings	DSP Operator/ CMWSSB
	Actions (Records of the announcements and relevant entities contacted) taken by CMWSSB	DSP and surrounding communities	In the event of Sightings	CMWSSB

Note # - A close and continuous monitoring during the construction phase through reputed intuitions such as NCSCM, Anna University, Chennai/ NIOT, Chennai/ IIT Madras to review the mitigation measures periodically and to take mitigation measures in the event of any adverse impacts to the coast.

It stipulates the post-clearance monitoring, which is required to be submitted half-yearly compliance reports in respect of the stipulated terms and conditions of the clearance to regulatory authorities, i.e., MoEF & CC and TNPCB. The monitoring activities specified in CRZ clearances are furnished in tables below:

15.2.2 Monitoring Activities requested by CZMAs

CZMA	Monitoring Activity	Frequency
Kancheepuram District (KDCZMA)	Marine quality including water quality and biological characteristics	Continuous
	Marine biodiversity	Twice in a year
	The concentration of toxic trace metals in the reject water	Periodical
	A moored data buoy shall be maintained in the vicinity of the effluent discharge to continuously monitor the changes in the selected physicochemical parameters (salinity, temperature, DO, current, etc.).	Periodical during the construction and operation phases
	The high salinity rejected water may be periodically monitored for the physiochemical and toxic trace metal contents through appropriate standard procedures.	Periodical
Tamil Nadu State (TNSCZMA)	Marine water at the outfall area	Every Quarter
	Periodical report on the site conditions to take mitigation measures on the event of any adverse impacts on the coast	Every Year
	Impact on the corals*, marine organisms, Turtle nesting etc. should be evaluated and monitored through experts (ecologists).	Not specified

15.2.3 Marine Environmental Monitoring proposed in the EIA Report

Marine environmental monitoring activities of Seawater & Sediment Quality, Marine Benthic Fauna, and Intake Seawater outfall have been proposed as shown in Table below

Monitoring	Purpose	Parameter	Frequency
Seawater & Sediment Quality	To monitor impacts on seawater and sediment quality	Measurements of levels of nutrients and heavy metals in water and sediment samples collected from sides at risk of pollution	Each season: April (Fair Weather), July (SW monsoon) and November (NE monsoon)
Marine Benthic Fauna	To determine the composition and distribution of major groups of fauna	Benthic fauna composition in the water outfall region	Each season as indicated above
Intake	To determine the incidence of entrapment and mortality of marine fauna	Screens on pump stations and the effectiveness of management measure	Each season as indicated above
	To determine the impact of entrainment within and external ponds/storage sump/well to assess the loss of fishery	Record an abundance of fauna within the pond/storage sump/well	Each season as indicated above
Seawater outfall	To determine the effect of increased temp/salinity on the plankton	Monitor abundance and distribution of both phytoplankton and zooplankton near the outfall. Video recording to elucidate the distribution of planktons may be conducted.	Each season as indicated above
		Monitor abundance and distribution of benthic animal communities near the outfall	Each season as indicated above

15.3 Environmental Sampling and Analysis Programme

The following Environmental sampling program shall be carried out as a minimum requirement by the Bidder before the commencing construction activity. Bidder to submit the Approach and methodology of environmental monitoring to the Employer's representative for review and approval. Bidder shall submit results of the Sampling program to the Employer's representative for approval. The initial environmental monitoring shall be carried for a duration of three months. Thereafter during the construction period, monthly reports to be submitted to the Employer's representative. The consolidated six-monthly reports are required to be submitted to MoEF &CC and TNPCB as part of regulatory compliance.

15.3.1 **Sampling Program – Part A**

A1. Ambient Air Quality

Parameters	No. of Locations	Frequency of monitoring per week (days)	Total Samples per week	Total samples per Month	Method
SO_2 (24 hrly)	5	2	10	40	West and Gaeke
NO_x (24 hrly)	5	2	10	40	Arsenite modified J and H
RSPM 10µm (24 hrly)	5	2	10	40	HVS
PM 2.5µm (24 hrly)	5	2	10	40	HVS with cyclone
CO (8 hourly)	5	2	10	40	As per MOEF Guidelines
Volatile organic compounds (VOCs) 24 hourly	5	2	10	40	As per MOEF Guidelines
Hydrocarbon (HC) 24 hourly	5	2	10	40	Gas Chromatographer

A2. Meteorology

Parameter	No. of Location	Frequency	Days	Total samples per Month	Method
- Wind speed - Wind direction - Relative humidity - Temperature, - Rainfall	1	1 hourly continuous	Monthly	1	Automatic weather station and as per IMD specification & MoEF Guidelines

A3. Noise Level

Parameters	No. of locations and Frequency	Minimum no. of sample per month
Equivalent noise level (Leq) for day time and night time (Ld, Ln, and Ldn).	5 locations & hourly intervals at each location	5

A4. Water Quality

Parameters	No. of Location	Frequency	Minimum No. of samples per month
(As per IS 10500) Colour, Odour, Temp, pH, turbidity, Total Hardness (Mg & Ca), TDS, total alkalinity, chloride, sulphate, nitrate, fluoride, Na, K, Calcium, Magnesium, phenolic compounds, Mineral oil, Cyanides, Anionic detergents, Residual chorine, Boron, Cadmium, Arsenic, Copper, Lead, Manganese, Iron, Chromium VI, Selenium, Zinc, Aluminium, Mercury, Pesticides, Total coliform, E-coli	2 groundwater + 3 surface water	5	5

A5. Soil Quality

Parameters	No. of Location and Frequency	Frequency	Total No. of samples per month
Bulk density, Salinity, Porosity, Texture Class (Percent wise silt, clay & sand), pH, Electrical conductivity, Cation exchange capacity, Sodium, Potassium, Nitrogen, Magnesium, Phosphorous, Sodium Absorption Ratio (SAR), Water holding capacity, Iron, Copper, Zinc, Manganese, Nickel, Permeability, physiochemical analysis and relevant metals.	5	Monthly	5

Note: Soil samples shall be collected from three different depths, i.e., 30 cm, 60 cm and 90 cm and homogenized samples to be used for analysis.

15.3.2 Sampling Program – Part B

B1. Marine Water Quality:

Sl. No.	Parameters	Number of Locations	Minimum Number of Samples per month
1.	Salinity		
2.	Electrical Conductivity		
3.	Temperature		
4.	Turbidity		
5.	Suspended Solids		
6.	pH		
7.	Dissolved Oxygen (DO)		
8.	Biological Oxygen Demand (BOD)		
9.	Nitrates as NO3-2		
10.	Ammonical Nitrogen		
11.	Nitrites as NO2-2	5	5
12.	Total Nitrogen		
13.	Inorganic Phosphate		
14.	Total Phosphate		
15.	Silicates		
16.	Phosphates as PO4-2		
17.	Chlorides as Cl-		
18.	Sulphates as SO4-2		
19.	Total Nitrogen		
20.	Heavy Metals		
20.1	• Zinc		
20.2	• Mercury		

Sl. No.	Parameters	Number of Locations	Minimum Number of Samples per month
20.3	• Cadmium		
20.4	• Lead		
20.5	• Copper		
20.6	• Iron		
21.	Oil and Grease		
22.	TOC/DOC		
23.	Petroleum Hydrocarbons		

B2. Sediment Quality:

The sediment samples will be collected using a suitable grab. After collection, the samples shall be sieved and subjected to Physico-chemical analysis. The samples collected will be tested for the following parameters:

Sr. No.	Parameters	Number of Locations	Minimum Number of Samples per month
1.	pH	4 & 1 from dredged material during project construction	5
2.	Texture		
3.	Oil & Grease		
4.	Petroleum Hydrocarbons		
5.	Organic Matter		
6.	Total Volatile Solids		
7.	Chlorides as Cl-		
8.	Phosphates as PO4-2		
9.	Nitrites as NO2-2		
10.	Nitrates as NO3-2		

Sr. No.	Parameters	Number of Locations	Minimum Number of Samples per month
11.	Sulphates as SO4-2		
12.	Sodium		
13.	Potassium		
14.	Magnesium		
15.	Total Kjeldahl Nitrogen		
16.	Heavy Metals		
16.1	Zinc		
16.2	Nickel		
16.3	Cadmium		
16.4	Copper		
16.5	Lead		
16.6	Mercury		
16.7	Iron		

B3. Biological Parameters:

The marine water and sediment samples shall be collected as analyzed for the following biological parameters:

B3.1 List of Biological Parameters for Marine Water Samples

Sr. No.	Parameters	Number of Locations	Minimum Number of Samples per month
1.	Primary Productivity	5	5
2.	Chlorophyll -a		
3.	Phaeophytin		

Sr. No.	Parameters	Number of Locations	Minimum Number of Samples per month
4.	Total Biomass		
5.	Oxidizable particulate organic carbon		
6.	Phytoplanktons		
6.1	Abundance		
6.2	Number and name of groups		
6.3	Total number and name of the species of each group present		
6.4	Density (total numbers of individual species present)		
6.5	Total biomass		
7.	Zooplanktons		
7.1	Abundance		
7.2	Number and name of groups		
7.3	Total number and name of the species of each group present		
7.4	Density (total numbers of individual species present)		
8.	Bacteriological parameters		

B3.2 List of Biological Parameters for Sediment Samples

Sr. No.	Parameters	Number of Locations	Minimum Number of Samples per month
1.	Benthic Organisms	5	5
2.	Meio fauna		

Sr. No.	Parameters	Number of Locations	Minimum Number of Samples per month
3.	Microfauna		
4.	Macrofauna		
5.	Abundance		
6.	Number and name of each group present		
7.	Total number and name of species of each group present		
8.	Density (total numbers of individuals of each species)		

15.4 Proposed Monitoring Forms

The template of Environmental Monitoring Forms which are required to be used during the pre-construction stage, Construction stage and Operation phase of the project are furnished in Tables below.

15.4.1 **Pre-Construction Phase (Tree cutting) Monitoring Forms**

The latest results of the below-monitoring items shall be submitted to the lenders as part of the Progress Report throughout the pre-construction phase.

15.4.1.1 *Air Pollution*

- Exhaust Gases

Date	Type of Construction Vehicles/ Equipment	Fleet/ Registration Number	Exhaust Gases Discharge Conditions				Frequency
(Day, Month, Year)			Items	Yes	No	If Yes, Measures Taken	Daily
			Black Smoke				
			White Smoke				
			Others (Specify)				

Logbook: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly.

If any problem arises, such vehicles and equipment to be sustained to use or be replaced by appropriate ones.

- Soil Dust (Dry Season only)

Date	**Location**	**Dust and dried sandy soil stirred up by construction activities**				**Frequency**
		Items	Yes	No	If Yes, Measures Taken (such as water supplying)	
(Day, Month, Year)	Construction Site including access roads	Dust				Daily
		Dried Sandy Soil				
		Others (Specify)				

Log Book: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly.

15.4.1.2 *Land Acquisition/ Resettlement (Progress of the tree cutting)*

Items	**Implementation (as of)**			**Frequency**
Cutting Schedule	1. As scheduled ( )	2. Delayed (months)	3. Postponed ( )	Once/ week
Total Value of Trees	1. Decided (Rs)	2. Under evaluation ( )	3. No action ( )	
Budget Allocation	1. Allocated by ( )	2. Under discussion ( )	3. No action ( )	
Compensation to Landowner	1. Compensated ( )	2. Under preparation ( )	3. No action ( )	
Auction for tree cutting	1. Conducted (when)	2. Under preparation ( )	3. No action ( )	
Waste Management	1. Properly Managed ( )	2. Under preparation ( )	3. No action ( )	

Progress of the preparation and implementation shall be submitted to CMWSSB monthly

15.4.2 Construction Phase Monitoring Form

The latest results of the below-monitoring items shall be submitted to the lenders as part of the Quarterly Progress Report throughout the construction phase

15.4.2.1 *Air Pollution*

- Exhaust Gases

Date	**Type of Construction Vehicles/ Equipment**	**Fleet/ Registration Number**	**Exhaust Gases Discharge Conditions**				**Frequency**
(Day, Month, Year)			Items	Yes	No	If Yes, Measures Taken	Daily
			Black Smoke				
			White Smoke				
			Others (Specify)				

Log Book: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly. If any problem arises, such vehicles and equipment to be sustained to use or be replaced by appropriate ones.

- Soil Dust (Dry Season only)

Date	**Location**	**Dust and dried sandy soil stirred up by construction activities**				**Frequency**
(Day, Month, Year)	Construction Site including access roads	Items	Yes	No	If Yes, Measures Taken (such as water supplying)	Daily
		Dust				
		Dried Sandy Soil				
		Others (Specify)				

Log Book: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly.

15.4.2.2 *Water Quality*

- On-site toilets

Date	**On-site Toilet Number/location**	**Sewerage water Conditions**				**Frequency**
(Day, Month,		Items	Yes	No	If Yes, Measures	Daily

Date	On-site Toilet Number/location	Sewerage water Conditions				Frequency
Year)					Taken	
		Black (sewage)water leakage				
		Bad odour				
		Emergency of Flies				
		Others (Specify)				

Log Book: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly.

- Turbidity (Seawater Turbidity during the installation of intake/outfall pipelines)

Date	Location of installation of Intake/ Outfall (GPS position)	Turbid water Conditions				Frequency
(Day, Month, Year)	Intake ( ) Outfall ( ) GPS Position	Items	Yes	No	If Yes, Measures Taken	Daily
		Silts				
		Sea sands				
		Bottom sediments				
		Others (Specify)				

Log Book: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly.

15.4.2.3 *Soil Contamination*

- Oil and Fuel leakage (spill)

Date	Type of Construction Vehicles/ Equipment	Fleet/ Registration Number	Oil/Fuel Leakage Conditions				Frequency
(Day, Month, Year)			Items	Yes	No	If Yes, Measures Taken	Daily

			Engine oil				
			Hydric power unit oil				
			Fuel				
			Others (Specify)				

Log Book: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly. If any problem arises, such vehicles and equipment to be sustained to use or be replaced by appropriate ones.

15.4.2.4 *Wastes*

- Construction Wastes and Debris

Waste Composition	**Waste Quantity (ton/ month)**	**Transportation, Disposal/Treatment Methods (Specify: ex. Registered Service Provider, Officially final disposal site, registered treatment facility (or company)**				**Frequency**
		Transport	**Disposal**	**Treatment**	**Remarks**	
Construction Debris						
Surplus Soil						
Toxic and Chemical Waste						
Other (specify)						

15.4.2.5 *Noise and Vibration*

- Noise from Construction Vehicles and Equipment

Visual Inspection Date	**Type of Construction Vehicles/ Equipment**	**Fleet/ Registration Number**	**Condition of Silencer equipped with construction vehicles/Equipment**				**Frequency**
(Day, Month,			Items	Yes	No	If Yes, measures are taken	Daily

Visual Inspection Date	**Type of Construction Vehicles/ Equipment**	**Fleet/ Registration Number**	**Condition of Silencer equipped with construction vehicles/Equipment**				**Frequency**
Year)						(such as water sprinkling)	
			Properly Equipped				
			Damaged				
			Large noise discharge				
			Others (Specify)				

Log Book: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly. If any problem arises, such vehicles and equipment to be sustained to use or be replaced by appropriate ones.

15.4.2.6 *Ecosystem*

- Turbidity

Date	**Location of installation of Intake/outfall (GPS position)**	**Turbid water Conditions**				**Frequency**
(Day, Month, Year)	Intake () Outfall ( ) GPS Position	Items	Yes	No	If Yes, measures are taken	Daily
		Silts				
		Sea sands				
		Bottom sediments				
		Others (Specify)				

- Environmental Education on Marine ecosystems and Sea Turtles

Date	**Venue**	**Agenda**	**Lecturer**	**Number of Participants**	**Materials paraded**	**Frequency**

(Day, Month, Year)				Community ( )		Twice/year
				Worker/ Labor ( )		
				Others (Specify)		
				Total ( )		

Participant list and educational materials shall be attached

- Sea Turtles Sightings

Item	Sighting Report					Frequency
Sea turtles	Time/ Date	Place (In or around Perur DSP construction site)	Sighted by whom (ex, Villager, Worker/labour, rumour and others	Description of the Sighting	Actions were taken to the sightings	In the event of sighting*
					See the Actions on Sea Turtle	

*During the egg-laying season of sea turtles, hearing survey on the sighting shall be done in the surrounding communities twice of the season

- Actions on Sea Turtle Sightings

Item	Sighting Report			Frequency
Actions on Sea turtle sighting	Construction Suspension Periods	Records of the announcements	Relevant entities contacted	In the event of Sighting

15.4.2.7 *Living and Livelihood*

- Seawater Turbidity during the installation of intake/outfall pipelines

Date	Location of installation of Intake/outfall (GPS position)	Turbid water Conditions				Frequency
(Day, Month, Year)	Intake ( ) Outfall ( )	Items	Yes	No	If Yes, Measures Taken	Daily

	GPS Position	Silts				
		Sea sands				
		Bottom sediments				
		Others (Specify)				

- Pipelines installation schedules and Installation (Construction) Management

Date	**Location**	**Management**				**Compensation budget and status (Specify)**	**Frequency**
		Type Space used (1. Paddy Field, 2. Farmland, 3. Others)	**Area (m^2)**	**Duration of use**	**Condition of Space**		Daily during the installation
(Day, Month Year)							

15.4.2.8 *Social Infrastructure and Services*

- Road Traffic

Date	**Location**	**Construction Vehicle Management**				**Frequency**
		Traffic Control (Specify the details)				**Daily**
		Time Restriction	**Avoidance of Rush Hour**	**Avoidance of Rush Hour**	**Others (Specify)**	
(Day, Month, Year)						

Log Book: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly.

- Commercial Activities (for the transmission pipelines installations)

Date	**Location**	**Management**				**Frequency**
		Traffic Control (Specify the details)				Daily during the installation
		Diversion Route	**Time Restriction**	**No Control**	**Others (Specify)**	

(Day, Month, Year)						

- Meetings with surrounding Communities (for the transmission pipelines installations)

Date	**Location / Community**	**Meeting Venue**	**Number of Participants**	**Agenda**	**Opinions Requests**	**Countermeasures**	**Frequency**
(Day, Month, Year)			Community ( )				Where necessary
			Officials ( )				
			Others (Specify)				
			Total ( )				

Participant list and meeting minutes shall be attached

15.4.2.9 *Risks of Infectious diseases such as HIV/AIDS*

- Health and Sanitation Education

Date	**Venue**	**Agenda**	**Lecturer**	**Number of Participants**	**Materials paraded**	**Frequency**
(Day, Month, Year)				Community ( )		Once/year
				Worker/Labor ()		
				Others (Specify)		
				Total ( )		

Participant list and educational materials shall be attached

15.4.2.10 *Working Conditions/Work safety for the Construction*

- Personnel Protective Equipment (PPE)

Date	**Monitoring Item**	**If any problems, measures are taken**	**Frequency**
(Day, Month, Year)	PPE: such as Helmet, Gloves, Masks, shoes) -		Daily

Log Book: to be prepared and recorded by the contractor(s) which is submitted to CMWSSB monthly.

15.4.2.11 *Accidents*

- Meetings with surrounding Communities

Date	Venue	Agenda	Lecturer	Number of Participants	Materials paraded	Frequency
(Day, Month, Year)				Community ( )		Once/year
				Worker/Labor ()		
				Others (Specify)		
				Total ( )		

15.4.3 **Operation Phase Monitoring Form**

The latest results of the below-monitoring items shall be submitted to the Employer on a biannual basis.

15.4.3.1 *Water Quality*

- Seawater and Potable Water

Sl. No.	Constituents	Seawater	Product Water	Frequency
1	Silt Density Index	✓		Daily
2	pH	✓	✓	Daily
3	Total Dissolved Solids	✓	✓	Daily
4	Temperature	✓	✓	Daily
5	Electrical conductivity	✓	✓	Daily
6	Turbidity	✓	✓	Daily
7	Residual chlorine	✓	✓	Daily
8	Boron content	✓	✓	Daily
9	Langelier index	-	✓	Daily
10	Oxidation-reduction	✓	-	Daily

	potential			
11	Alkalinity	✓	✓	Daily
12	Chloride	✓	✓	Daily
13	Hardness	✓	✓	Daily

Operational Monitoring Report on the Seawater and Product Water monitored at DSP can be attached.

- Brine Concentration

Date	**Sampling Location**	**Brine Concentration (ppt)**	**Remarks**	**Frequency**
				Daily

- Domestic Wastewater (Sewage Treatment Plant)

Monitoring Item	**Method**	**If any negative results measures – Action to be taken**	**Frequency**
Bad Odor	Visual Inspection (Common sensation)		Once/month
Water Leakage	Visual Inspection		
Generation of flies	Visual Inspection		
Other necessary actions to be monitored as per the instruction and manuals on the operation and maintenance of aerated sewage treatment facilities (STP) is to be installed.			Once/month (or instructions of the Contractor of STP)

15.4.3.2 *Ecosystem*

- Environmental Education on Marine Ecosystems and Sea Turtles

Date	**Venue**	**Agenda**	**Lecturer**	**Number of Participants**	**Materials paraded**	**Frequency**
(Day,				Community ( )		Once/year

Month, Year)				Worker/Labor ( )		
				Others (Specify)		
				Total ( )		

Participant list and educational materials shall be attached

- Sea Turtles Sightings

Item	**Sighting Report**					**Frequency**
Sea turtles	Time/ Date	Place (In or around Perur DSP site)	Sighted by whom (ex, Villager, Worker/labour, rumour and others	Description of the Sighting	Actions were taken to the sightings	In the event of Sighting*
					See the Actions on Sea Turtle Sightings (specified below)	

*During the egg-laying season of sea turtles, hearing survey on the sighting shall be done in the surrounding communities twice of the season

- Actions on Sea Turtle Sightings

Item	**Sighting Report**			**Frequency**
Actions on Sea turtle sighting	Construction Suspension Periods	Records of the announcements	relevant entities contacted)	In the event of Sighting

15.4.4 **Monitoring Format for EIA And CZMAS Recommendations**

15.4.4.1 *Construction Phase*

Environmental Items	**Monitoring Items**	**Parameters**	**Frequency**	**Recommended by**	**Monitoring Results**
General Environment	Site conditions	Any adverse impacts on the coast	Every Year	Tamil Nadu State CZMA	

15.4.4.2 *Operation Phase*

Environmental Items	Monitoring Items	Parameters	Frequency	Recommended by	Monitoring Results
Water Quality	Seawater & Sediment Quality	Nutrients and heavy metals	Each season: April (Fair Weather), July (SW monsoon) and November (NE monsoon)	EIA Report	
Ecosystem	Marine Benthic Fauna	Benthic fauna composition	Each season as indicated above	EIA Report	
Ecosystem	Intake entrapment of marine fauna	Screens on pump stations and Effectiveness of management measure	Each season as indicated above	EIA Report	
Ecosystem	Entrainment of marine fauna	Abundance of fauna within the pond/ storage sump/well	Each season as indicated above	EIA Report	
Ecosystem	Seawater outfall	Abundance and distribution of both phytoplankton and zooplankton	Each season as indicated above	EIA Report	
Ecosystem		Abundance and distribution of benthic animal communities	Each season as indicated above	EIA Report	
Water Quality/ Ecosystem	Post-project marine quality	Marine quality,	Continuous	Kancheepuram District CZMA	

Environmental Items	**Monitoring Items**	**Parameters**	**Frequency**	**Recommended by**	**Monitoring Results**
		including water quality and biological characteristic.			
Ecosystem	Marine biodiversity	Not specified	Twice in a year	Kancheepuram District CZMA	
Water Quality	Reject water	Concentration of toxic trace metals	Periodical	Kancheepuram District CZMA	
Water Quality	Changes in the selected physicochemical parameters	Salinity, temperature, DO, current etc.	Periodical during the construction and operation phases	Kancheepuram District CZMA	
Water Quality	The high salinity reject water (maybe monitored through appropriate standard procedures)	Physiochemical and toxic trace metal contents	Periodical	Kancheepuram District CZMA	
Water Quality	Marine water	Parameter is not specified/ to be monitored at the outfall area	Every Quarter	Tamil Nadu State CZMA	
General Environment	Site conditions	Any adverse impacts on the coast	Every Year	Tamil Nadu State CZMA	
Ecosystem	Impact on marine organisms, Turtle nesting etc.	Marine organisms, Turtle nesting etc.	Not specified (to be monitored by experts)	Tamil Nadu State CZMA	

16. SOCIAL MANAGEMENT PLAN

Social safeguard interventions play a major role in bringing understanding and harmony while addressing the impact of infrastructure development which is meant for the greater interest of the society and the people embedded. Hence, the objective of social safeguard intervention is to adhere to JICA's guideline, ISO and the international standards during construction and operation of Chennai Perur 400 MLD Desalination Plant.

16.1 Scope of Social Safeguard Intervention

The scope of work shall include but not be limited to the following:

16.1.1 Social Management Strategies, Plan and Execution

- After award of the contract and before the start of work, the Contractor shall review the available Social Management Plan (SMP) for the project available with CMWSSB. The contractor shall duly update the SMP to ensure compliance with all applicable legislation and regulations of State / Central Government, JICA's Guidelines and IFC Performance Standards on Social Sustainability. The SMP shall incorporate the requirements stipulated in the Project's SIA Report and conditions of approval from State/Centre Regulatory agencies. The SMP shall clearly define roles, responsibilities, reporting requirement and budgetary allocations for implementation of mitigation measures. In case of any revision to SMP; shall be submitted by the Contractor to CMWSSB for necessary approval before initiating any groundwork.
- Separate Social Management Plans for Construction, maintenance and Operations Stages shall be prepared to address the impacts associated with construction, maintenance and operation activities on the workforce engaged and surrounding communities. These plans shall incorporate the requirements stipulated in the Project's SIA Report, applicable legislation and regulations, conditions of approval from State/Centre Regulatory agencies and also considering best practices and good engineering practices, as applicable.

16.1.2 Labour Influx and Worker's Camp Management Plan

The labour influx and worker's camp management plan, including the process for mitigating construction-related impacts on the local community are given below.

16.1.2.1 *Labour Camp Management*

i) The contractor preferably will use unskilled/semi-skilled labour from the local area to give the maximum benefit to the local community whenever this is possible.

ii) The contractor will follow all relevant provisions of the Building and the other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 for construction and maintenance of labour camp.

iii) Pooled transportation facilities as may be required, shall be provided by the contractor. The location, layout and basic facility provision of labour camp will be submitted to Engineer for approval prior to its construction.

iv) The contractor will provide and maintain well-ventilated living accommodation and ancillary facilities for workers, including adequate working, eating, and sleeping arrangements for field workers functionally, hygienically and safely.

v) The contractor will construct and maintain all labour accommodation in such a fashion that uncontaminated clean water is available for drinking, cooking, bathing and washing.

vi) Clean and cool drinking water will be made available for workers by the contractor at the construction site/labour camp/s. The Contractor will also provide potable water facilities at the construction site in an accessible place, as per standards set by the Building and other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996. Provision of mobile drinking water counter/kiosk, with 300-litre capacity, with at least two taps, with a bottom tank, to collect wastewater will be placed at a suitable place near worksites.

vii) Workers shall not be allowed to defecate in the open. Proper mobile toilets fitted with a septic tank will be provided by the contractor. Separate toilets/bathrooms, wherever required, will be provided for male and female, marked in sign as well as in vernacular in the construction camp.

viii) Adequate freshwater supply will be ensured in kitchen/mess, bathrooms, toilets and urinals.

ix) Fuelwood will not be allowed for cooking at labour camps. LPG cylinders as cooking fuel will be provided at labour camp by the contractor.

x) Regular damp cleaning, sweeping, disinfecting and sanitizing will be ensured at the labour campsite.

xi) The contractor will ensure that the sewage system for the camp will be designed, built and operated in such a manner that no health hazard occurs and no pollution to the air, groundwater or adjacent watercourses take place and biologically treated, to consistently deliver excellent effluent quality with biweekly test reports.

xii) The contractor will provide stability to the marine outfall system even during cyclonic conditions, and appropriate anchor shall be provided.

xiii) The contractor will ensure that the pipelines such as intake pipeline and outfall line and intake arrangement in the sea and the pipeline intake and outlet shall not cause any hindrance to the movement of the local communities including the fishermen and the movement of fishing vessels. Any hindrance impacted the livelihood of fishermen partially/entirely during the construction, in particular, construction of intake-well pipeline; will attract substance grant for the period the livelihood was impacted.

xiv) The contractor will ensure that there is no displacement of people, housing or fishing activity as a result of the project; as nothing of that sort was observed and envisaged prior to drafting the scope.

16.1.2.2 *Provision of First Aid/Medical Facilities and Emergency Response Arrangements*

i) The Construction Safety Plan to be prepared by the Contractor will identify necessary actions in the event of an emergency. This plan will be submitted for Engineer's approval along with the Work Program at the mobilization stage itself.

ii) The Contractor will arrange for:

- Readily available first-aid box, including an adequate supply of sterilized dressing materials and appliances, as per rules shall be provided in work zones and at the campsite/s.
- Registered medical practitioner (Doctor) and trained First Aid personnel will be available at the construction site.
- Emergency numbers will be displayed at camp, plant and construction sites.
- Availability of suitable transport at all times to take an injured or sick person(s) to the nearest hospital shall be made.

iii) The contractor will make required arrangements so that in case of any mishap on the construction site, all necessary steps can be taken for prompt first aid treatment.

iv) First aid facilities and free emergency care shall be provided to all workforce and third party. No cost shall be recovered from them on this account.

v) All supervisory staff shall be provided with mobile phones for better communication across operational areas, in case of emergency or otherwise.

vi) The Contractor shall provide information to his workers on methods of avoiding COVID-19 pandemic, sexually transmitted diseases and infection by HIV/AIDS. The information about the location of camps shall be known to the District Societies for Prevention of COVID-19 and HIV/AIDS. The awareness programs launched for the prevention of COVID-19 and HIV/AIDS should be well documented.

16.1.3 Stakeholder Engagement Strategies, Plan and Implementation

i) SMP, which explains interaction with the community, including project information disclosure and emergency response planning relevant for the community. This sub-plan should cover means and methods to inform affected population about construction schedule and expected impacts such as access limitation to properties if any, and also spell out the grievance redressal mechanism available to the communities to ensure any concerns brought to the CMWSSB are resolved appropriately and on time.

ii) The Contractor shall implement all requirements of the SMP approved by CMWSSB during the entire period of the contract, i.e. during Construction Stage and Operation Stage of the Desalination Plant and associated facilities.

iii) Operation and Maintenance of aforesaid the Desalination Plant and associated facilities are to be carried out strictly as per the approved SMP and as directed by the CMWSSB and State Norms.

16.1.4 **Social Monitoring Plan (SMoP)**

i) SMoP shall be prepared to ensure that the envisaged purpose of the SMoP is achieved across all stages of the project. Performance indicators will be developed for critical social conditions. For each of the indicators, the monitoring plan will specify parameters to be monitored, the location of monitoring sites along with frequency and duration of monitoring. The monitoring plan will also specify applicable standards, implementation and supervising responsibilities and reporting requirements.

ii) The Contractor shall regularly monitor the quality of the working sites and their surroundings in terms of social performance indicators as specified in SMP and submit the monitoring results to CMWSSB. The Contractor shall also be responsible for periodic submission of Monitoring Reports to the Regulatory Agencies in compliance with requirements of the SMP.

iii) It may be noted that the status of social monitoring shall be communicated to JICA as part of Quarterly progress report. JICA would disclose information on the status of social monitoring of the project in collaboration with CMWSSB in its website in order to ensure transparency, accountability and to promote the participation of various stakeholders.

16.2 Work Requirements

16.2.1 **Site**

The proposed Chennai Perur 400 MLD Desalination Plant (DSP) is located in Nemmeli revenue village, Nemmeli Panchayat in Thiruporur Taluk (Thiruporur Block) of Chengalpattu district (earlier Kanchipuram District), Tamil Nadu State, India. The village is bifurcated into East and West part by the State Highways- 49, i.e. East Coast Road (ECR) towards Mamallapuram. In North-to-South direction. However, the proposed plant is located in the Eastern part of Nemmeli village and on the shore of Bay-of-Bengal. Moreover, this plant will be constructed about 0.8 kilometres distance on the North of already existing Nemmeli 100 MLD plant.

16.2.2 **Socio-economic Profile**

Nemmeli village comprises of ten habitations viz.; Pudukalpakkam, Nemmeli, Nemmeli kuppam, Kannima Nagar, Perur, Perur colony, Sulerikadu, Sulerikadu colony, Sulerikaattu kuppam and Krishnan karanai, Out of these ten habitations, Pudukalpakkam, Nemmeli kuppam, Sulerikaattukuppam habitations are on the eastern side of East Coast Road (ECR) with a distance of 1.865 Km, 815 m and 2.365 Km apart respectively. All these three habitations belong to fishermen communities and are covered under the Most Backward Class (MBC) category. Other habitations are on the western side and are substantially distanced from seashore to get affected from seawater flood in case of Tsunami and periodic cyclones.

Referring to Chennai Perur 400 MLD DSP; Nemmeli kuppam and Sulerikaattukuppam are two habitations adjacent to the plant in North and South direction respectively. However, from plant construction and operation perspective, Nemmeli Kuppam habitation is expected to have more interactive process than other habitations. Hence, a further detail socioeconomic aspect of Nemmeli Kuppam is presented below.

There are 166 houses in Nemmeli kuppam, of which owners have occupied 142 houses, and rest are occupied by 24 tenants. All the 166 houses have patta land. After Tsunami devastation, 124 houses were being constructed in by the NGO 'World Vision' after the Tsunami devastation in the year 2004. The total population of this habitation is 442, of which 230 are male, and 212 are female. Of the 166 houses, owners have occupied 142 houses, and 24 tenants are there.

All 142 families of this fishermen habitation practice Hindu religion (Hindu Meenavar parvatharaja kulam) and belong to Most Backward category defined by Government of Tamilnadu. Only a few tenants who have come from other areas belong to Most Backward and Backward communities. The habitants are literate and educated, except few people above 80 years old.

Occupationally, in general, men are engaged in fishing and allied activities. Few men are working in the companies and offices during daytimes. Women are engaged in selling of fish in neighbouring areas and dry fish preparation. Educated youngsters are working in offices and companies located in ECR and OMR. Two of them are employed in the existing 100 MLD desalination plant located nearby. Few fishermen are doing fishing in the morning, and during the daytime, they are employed in the local companies. Nearly 30 members (women) from this habitation are employed under "The Mahatma Gandhi National Rural Employment Guarantee" program by Ministry of Rural Development, Government of India. They are getting employment for 100 days in a year on a wage rate of INR 256/day. On an average family earn INR 12000 to INR 15000 per month from fishing activity and around INR 10000 to INR 15000 as their wages from the companies.

There are 4 Self Help Groups run by women of this habitation, and mainly they do microfinance through their loan amount. There is only one Public health sub-centre available for this Nemmeli village panchayat wherein a nurse is available for vaccination and immunization purpose.

16.2.3 Issues and Impact

Chennai Perur 400 MLD DSP is planned to be constructed in a land belonging to M/s Arulmigu Alavandar Nayakkar Trust (a religious and charitable group) maintained by the Hindu Religion and Charitable Endowments (HR&CE) Department of the Government of Tamil Nadu (GOTN)), which is leased for 30 years to CMWSSB. There are no settlements or households that exist on the portion of the land leased. However, in the DSP site, there are two burial grounds; but the plant layout has been arranged so that no facility would be constructed in the burial grounds. There is the presence of an open-well with a pump house connected to three-phase line is used for daily water supply through transmission pipeline to Nemmeli Kuppam and Perur colony habitations. In case the construction and operation of the plant will require to interrupt the water supply to the said habitations; alternate arrangement should be placed for uninterrupted water supply prior to disconnecting existing water supply.

16.3 Bill of Quantity

16.3.1 Peripheral Development

16.3.1.1 *Nemmeli Kuppam Habitation*

i) Landing Centre Protection: During the intake well construction for Chennai Perur 400 MLD DSP there are possibilities of seawater flow towards Nemmeli Kuppam habitation from East-to-West direction causing soil erosion. As a result, the fishermen boat parking area and the landing centre might get affected. Hence, the provisional budget for the purpose needs to be allocated for probable construction activities for the protection of the landscape.

ii) Community Toilet: One community toilet is present in the southern side of the plant site for the use of Nemmeli Kuppam habitation, which will be inaccessible once the boundary wall of the plant site is constructed. Though currently this community toilet is not in use due to non-availability of water and is dilapidated; provisional budget for community usable toilet needs to be allocated, in case the requirement arises in due course.

iii) Bore Well for Community Potable Water: There is the presence of open-well from where water is pumped through a three-phase connected pump house to Perur and Perur colony in the Western side of ECR is supplied water from this well. In case the current water supply system to both the habitation is abandoned due to the boundary wall and upcoming plant; provisioning budget for the bore-well system with transmission pipeline in said habitations along with transmission pipeline to the community storage system to both habitations for the supply of potable water is suggested.

iv) Subsistence Grant for partial loss of livelihoods: Understanding possibilities of livelihoods disruption during construction period intake well; provisional budget for subsistence grant to one member of primary Fisherman cooperative Society (PFCS) for the period their livelihood is affected considering 8 months per year as fishing period. However, in case any of the family member/s employed by the contractor part-time or full-time basis should not be entitled to such a subsistent grant in a typical case. However, there can be flexibility in adhering the condition according to the ground situation.

16.3.1.2 *Public Consultation*

While there will be construction and operation of the plant activities, regular public consultations need to be conducted to develop a better understanding among the habitats around the plant area; particularly Nemmeli Kuppam. The public consultation should be recorded audio-visually as well as in print material. Hence, budgetary provision towards this expenditure to be made accordingly.

16.3.2 **Dispensary within Plant Premises**

Near the Nemmeli village, there is one Health Sub-centre, which is managed by a Nurse. Hence, understanding the intensity of construction work; it is suggestive of setting up and operate dispensary within the plant site during the construction period. Accordingly, 24 hours availability of one doctor and two health support staff within the plant site is felt highly essential. The dispensary should procure essential First aid material, medicines and health kits according to the regulatory compliance. In addition, the contractor should procure ambulance (Multipurpose with advance life support system) for 24 hours availability to cater to the emergency needs. Also, the ambulance service may be extended to the peripheral habitants in the high-end emergency case as part of humanitarian assistance and cordial rapport building.

16.3.3 Public Awareness and Capacity Building

Awareness programmes within the plant site and focussed periphery particularly related to health due to conglomeration of external and local manpower for engagement in the construction of the plant. Apart from HIV/AIDS-related issues; the recent Covid-19 pandemic is alarming for the contractor to conduct periodic health check-up camps within and periphery of the plant site. In addition, towards a goodwill building and long-term livelihood support strategy; vocational/skill development training needs to be conducted.

It is often observed gaps in understanding social issues by the personnel more involved/focused on engineering technical aspects. Hence, periodical orientation will help to hinder to handle some of the social aspects sensitively in the work environment.

16.3.4 Natural Disaster and Relief

The Bay of Bengal and the coast of Tamilnadu is vulnerable to the impact of the cyclone and other natural disaster like Tsunami. Hence, to address to the immediate tragic; natural disaster relief fund should be available for immediate response during and aftermath of such disaster in terms of health and food security. However, this fund does not create scope for infrastructure development.

16.3.5 Engagement of Social specialist to implement and address related issues

Social Specialist having substantial experience in similar activities needs to be appointed by the Contractor after awarding of the contract and before the start of work; to carry out social safeguard intervention activities within the plant premise and the peripheral.

16.4 Technical Schedule

The Bidder shall provide his Social Management Plan (SMP) in detail to demonstrate the procedures that will be used to ensure that the social concerns and requirements as outlined in contract conditions are satisfactorily met.

After award of contract and before the start of work, the Contractor shall review the available Social Management Plan (SMP) for the project available below with CMWSSB. The contractor shall duly update the SMP to ensure compliance with all applicable legislation and regulations of State / Central Government and also with Sustainability Guidelines of JICA and IFC Performance Standards on Social Sustainability. The SMP shall incorporate the requirements stipulated in the Project's SIA Report and conditions of approval from State/Centre Regulatory agencies. The SMP shall also clearly define roles, responsibilities, reporting requirement and budgetary allocations for implementation of mitigation measures. Any revision to SMP shall be submitted by the Contractor to CMWSSB for necessary approval before initiating any groundwork.

The SMP shall identify the potential social impacts from the various construction and operations and maintenance activities to be undertaken in the Contract and set out in detail the approach he will adopt in mitigating these impacts to ensure that the impacts are minor and confined to a short period.

The Bidder shall provide separate descriptions of its proposals for minimizing any adverse social impacts/effects during the construction phase and the subsequent operations and maintenance phase.

CONSTRUCTION, OPERATION AND DECOMMISSIONING PHASE MITIGATION MEASURES FOR DESALINATION PLANT AND ASSOCIATED INTAKE AND OUTFALL UNDERSEA PIPELINES

Required approvals and permits are also needed during operations and decommissioning phase, therefore, CMWSSB needs to ensure the required compliance

Sl. No	Systems/ Impacts	Action to be taken	Time frame	Responsible agencies	Responsible Agency for Review and Monitoring
1.1	Rapid Social Screening	The contractor shall undertake the social screening survey within the proposed project area and identify potential social impacts due to proposed plants construction, operations decommissioning. Social screening should identify but not limited to the following aspects: ▪ Permanent and temporary economic and physical displacement of the communities. ▪ Potential impacts of livelihood and income. ▪ Potential impacts on common property resources, fishing area	Pre-construction, Operations & Decommissioning phase	Prospective Contractor/ Concerned Departments	Project head /in-charge CMWSSB
1.2	Construction of labour camps	• Contractor shall follow all relevant provisions of the Contract Labour (Abolition and Regulation) Act, 1970and the Building and the other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 for construction and maintenance of labour camp and other applicable laws. • The location, layout and basic facility provision of each labour camp will be submitted to CMWSSB Engineer prior	Pre-construction, Operations & Decommissioning phase	Prospective Contractor/ Concerned Departments	Project head /in-charge CMWSSB

Sl. No	Systems/ Impacts	Action to be taken	Time frame	Responsible agencies	Responsible Agency for Review and Monitoring
		to their construction. • The construction will commence only upon the written approval of the Engineer. • The contractor shall maintain necessary living accommodation and ancillary facilities functionally and hygienically and as approved by the Engineer. • The contractor shall provide an adequate number of toilets, bathing area, kitchen and safe fuel for cooking. • The labour camps shall be designed to protect from heat, rains, flooding, insects, snakes and mosquitoes. It should have adequate provisions for an emergency response such as first aid and fire safety etc. • All temporary accommodation must be constructed and maintained			
1.3	Risk Assessment and preparation of management plans	Risk and hazards associated with different construction activities shall be identified by the contractor, and accordingly, management plans shall be prepared for implementation on site such as : • Construction Labour Management Plan; • Emergency Response Plan; and • Construction Demobilization Plan.	Pre-construction Operation & Decommissioning phase	CMWSSB / Prospective Contractor	Project head /in-charge CMWSSB

Sl. No	Systems/ Impacts	Action to be taken	Time frame	Responsible agencies	Responsible Agency for Review and Monitoring
1.4	Disaster Management Plan	• The CMWSSB shall identify the key risks associated with each component/ activities for entire project life cycle (construction, operations, & decommissioning) and shall prepare Disaster Management Plan (DMP) for the proposed plant. • Further, the DMP for the plant should be synchronized with the district disaster management plan for off-site emergencies. • Contractor shall ensure the availability of required resources for the implementation of DMP at the site and hinder local communities in handling disaster and emergency response	Pre-construction Operation & Decommissioning phase	CMWSSB / Prospective Contractor	Project head /in-charge CMWSSB
1.5	Information disclosure and stakeholder consultations	The contractor, in consultation with CMWSSB, shall undertake detailed mapping and analysis of key stakeholders which includes the community. Based on the outcomes of stakeholder analysis, shall prepare and implement a stakeholder engagement plan and regularly update the plan and undertake the proper reporting & documentation (minutes and photographs) of the stakeholder engagements. The CMWSSSB and contractor shall ensure that stakeholder, including impacted communities, are consulted and made aware of the project's outcome, risks/ impacts, mitigation measures and time frame.	Pre-construction Operation & Decommissioning phase	CMWSSB / Prospective Contractor	Project head /in-charge CMWSSB

Sl. No	Systems/ Impacts	Action to be taken	Time frame	Responsible agencies	Responsible Agency for Review and Monitoring
1.6	Grievances management	The CMWSSSB and contractor shall establish the formal system for Grievance management (GRM). The GRM should cover the staff, contracted workers and community. The contractor shall ensure the wider publicity of functioning and availability of GRM. And designate the required resources for the effective functioning of GRM. The stakeholders, including communities, shall be made aware of the presence of GRM since the inception of the project.	Pre-construction Operation & Decommissioning phase	CMWSSB / Prospective Contractor	Project head /in-charge CMWSSB
1.7	Living and Livelihood	Intake/outfall installation sea areas • Visual inspection on turbid water in the sea during installations of intake/outfall pipelines • Pipelines installation schedules • Installation (Construction) Management	Daily for the installation period	CMWSSB / Prospective Contractor	Project head /in-charge CMWSSB
1.8	Social Infrastructure and Services	• Implementation of meetings with communities, • Organising awareness camps	Construction site and surrounding communities where necessary	CMWSSB / Prospective Contractor	Project head /in-charge CMWSSB
1.9	Risks of cyclones and tsunami	• Contractor shall ensure that adequate measures and communication system is available in case of any natural hazard; • Evacuation plan shall be in place for the site.	Construction, operation and decommissioning phase	Prospective contractor/ respective operating agency	Project head /in-charge CMWSSB

Sl. No	Systems/ Impacts	Action to be taken	Time frame	Responsible agencies	Responsible Agency for Review and Monitoring
2.0	Risk of Pandemic diseases such as COVID-19	Implementation of Health and Sanitation awareness and education	Construction site and surrounding communities Once/Month	CMWSSB / Prospective Contractor	Project head /in-charge CMWSSB
2.1	Risk of infectious diseases such as HIV/AIDS	Implementation of Health and Sanitation education on STD.	Construction site and surrounding communities Twice/Year	CMWSSB / Prospective Contractor	Project head /in-charge CMWSSB
2.2	Working Conditions/Work Safety	Visual inspection on the utilisation of PPE by workers/labours	Construction site Daily	CMWSSB / Prospective Contractor	Project head /in-charge CMWSSB
2.4	Removal of temporary construction Structures and demobilization of construction machinery	• Contractor to prepare site restoration plans, the plan is to be implemented by the contractor prior to demobilization. • On completion of the works, all temporary structures will be cleared away, all rubbish cleared, excreta or other disposal pits or trenches filled in and effectively sealed off and the site left clean and tidy, at the contractor's expenses, to the entire satisfaction of the engineer.	After completion of the project	Prospective contractor	Project head /in-charge CMWSSB
2.5	Labour camp & facilities	Setting up of labour camps needs to be done as per the above-mentioned guidelines and procedures. • Adequate potable water facilities, sanitation and drainage,	Construction operation and	Perspective contractor	Project head /in-charge CMWSSB

Sl. No	Systems/ Impacts	Action to be taken	Time frame	Responsible agencies	Responsible Agency for Review and Monitoring
		etc., in conformity with the Indian labour laws such as building and other construction workers act and IFC guidelines for workers accommodation, shall be ensured. • The contractor shall also guarantee the following: i. The location, layout and basic facility provision of each labour camp will be submitted to Engineer prior to their construction. ii. The construction will commence only upon the written approval of the Engineer. iii. The Contractor shall construct and maintain all labour accommodation in such a fashion that uncontaminated water is available for drinking, cooking and washing. iv. Supply of sufficient quantity of potable water (as per IS) in every workplace/labour campsite at suitable and easily accessible places and regular maintenance of such facilities. v. The sewage system for the camp shall be designed, built and operated in such a fashion that no health hazards occur and no pollution to the air, groundwater or adjacent watercourses take place. Ensure adequate water supply is to be provided in all toilets and urinals.	decommissioning phase		

Sl. No	Systems/ Impacts	Action to be taken	Time frame	Responsible agencies	Responsible Agency for Review and Monitoring
2.6	Compliance to Indian labour Laws	• The contractor and CMWSSB should ensure the compliance of applicable Indian Labor Laws such as Factories Act 1948, Building and Other Construction Workers act 1996, Inter-State Migrant Workmen Act 1979, Contract Labor (Regulation & Abolition) Act 1971, Workmen Compensation Act 1923 Child Labour Prohibition &Regulation Act 1986, Minimum Wages Act 1948, Employee state insurance Act 1948, Employees Provident fund Act 1991, Payment of Wages Act 1936, Payment of bonus act 1965, Equal Remuneration Act 1976, and Payment of Gratuity Act 1972 and other International Labour organization conversions ratified by India • Maintain the required document at the site and regularly submit the compliance report to the concerned department and conduct internal and external labour audit	Construction/Maintenance, Operations and decommissioning phase	CMWSSB / Prospective contractor	Project head /in-charge CMWSSB & External Auditor
2.7	First Aid	The contractor shall arrange for: • A readily available first aid unit, including an adequate supply of sterilized dressing materials and appliances as per the Factories Rules in every work zone. • Availability of suitable transport at all times to take an injured or sick person(s) to the nearest hospital • Tie up with nearby hospitals.	Construction, maintenance, operation and decommissioning phase.	Prospective contractor/ respective operating agency	Project head /in-charge CMWSSB

Annexures

The following annexures are included with this RFP Report:

Annexure 1 – Social Policy, Legal and Administrative Framework

- Annex 1.1: JICA Environmental and Social Framework
- Annex 1.2: Screening and Categorisation
- Annex 1.3: Regulations, Laws and Permitting
- Annex 1.3: Institutional Arrangements

Annexure 2 – Salient Features of Key Applicable Labour Laws

Annexure 1 SOCIAL POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

Annex 1.1. JICA Environmental and Social Framework

JICA requires the consideration of social matters in all aspects of JICA operations and the requirements for social considerations as described in JICA guidelines (April 2010). In addition, adherence to International Performance Standards has been suggested. JICA guidelines endeavours to achieve transparency, predictability, and accountability in support for and examination of social considerations.

Annex 1.2. Screening and Categorisation

The requirement of the JICA's Guidelines is dependent on "project categorization" of the Project, which is stipulated in the JICA's Guidelines, as shown in Table 1. Currently, the Chennai Seawater Desalination Project (the Project) has been classified as "Category B" by JICA. However, if the project is likely to have any significant adverse impacts on the environment and society in the Study, the Project may be recategorized as "Category A".

Table 1. Project Category in the JICA Guidelines

Category	Description
A	Proposed projects are classified as "Category A" if they are likely to have significant adverse impacts on the environment and society. Projects with complicated or unprecedented impacts that are difficult to assess, or projects with a wide range of impacts or irreversible impacts, are also classified as "Category A". These impacts may affect an area broader than the sites or facilities subject to physical construction. "Category A", in principle, includes projects in sensitive sectors, projects that have characteristics that are liable to cause adverse environmental impacts, and projects located in or near sensitive areas.
B	Proposed projects are classified as "Category B" if their potential adverse impacts on the environment and society are less adverse than those of "Category A" projects. Generally, they are site-specific; Few if any are irreversible; and in most cases, normal mitigation measures can be designed more readily.
C	Proposed projects are classified as "Category C" if they are likely to have a minimal or little adverse impact on the environment and society.

Based on the Initial Environmental Examination carried out by JICA, the proposed Chennai Perur 400 MLD desalination project is categorised under "B". Since the project is not located in a sensitive area, nor has sensitive characteristics, nor falls into sensitive sectors under the JICA guidelines for environmental and social considerations (April 2010), and its potential adverse impacts on the environment are not likely to be significant. Details of categorisation are available in JICA website:

https://www.jica.go.jp/english/our_work/social_environmental/id/asia/south/india/c8h0vm0000ahdaf4.html

Annex 1.3. Regulations, Laws and Permitting

There are various acts, rules, policies and regulations currently in force in India that deal with social issues that could apply to infrastructure development. Some of the specific regulatory compliance requirements of the subproject are presented below.

i) Tamil Nadu Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Rules, 2017

The Act provides for transparent and acceptable fair and enhanced compensation and assistance measures. It stipulates a more consultative and participatory approach in dealing with the Project Affected Persons. It emphasizes the rehabilitation and resettlement of the PAPs before the implementation of the actual project.

ii) The National Resettlement and Rehabilitation Policy (Ministry of Rural Development, Department of Land Resources), 2007

The NRRP 2007 was adopted by the Government of India on 31st October 2007 to address development-induced resettlement issues. The NRRP stipulates the minimum facilities to be ensured for persons displaced due to the acquisition of land for public purposes and to provide for the basic minimum requirements. All projects leading to the involuntary displacement of people must address the rehabilitation and resettlement issues comprehensively. The State Governments, Public Sector Undertakings or agencies, and other requiring bodies shall be at liberty to put in place greater benefit levels than those prescribed in the NRRP.

The objectives of the Policy are:

- to minimize displacement and to promote, as far as possible, non-displacing or least displacing alternatives;
- to ensure adequate rehabilitation package and expeditious implementation of the rehabilitation process with the active participation of the affected families;
- to ensure that special care is taken for protecting the rights of the weaker sections of society, especially members of the Scheduled Castes and Scheduled Tribes, and to create obligations on the State for their treatment with concern and sensitivity;
- to provide a better standard of living, making concerted efforts for providing sustainable income to the affected families;
- to integrate rehabilitation concerns into the development planning and implementation process; and
- where displacement is on account of land acquisition, to facilitate the harmonious relationship between the requiring body and affected families through cooperation.

The NRRP is applicable for projects where over 400 families in the plains or 200 families in hilly or tribal or Desert Development Program (DDP) areas are displaced. However, the basic principles can be applied to resettling and rehabilitating regardless of the number affected. NRRP's provisions are intended to mitigate adverse impacts on Project Affected Families (PAFs). The non-title holders, under NRRP, are recognized as the people living in the affected area not less than three years at the time of declaration of the area as affected area. The NRRP addresses vulnerable families with adequate entitlements and provides special provisions for Scheduled Castes (SC) and Scheduled Tribes (ST) Families. The NRRP takes in to account all the transparency as far as consultation, dissemination of information, disclosure and grievance is concerned. However, the law relating to the acquisition of privately owned immovable property is the Land Acquisition Act of 1894.

iii) The Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act, 2014

This act aims explicitly to protect the rights of urban street vendors and to regulate street vending activities. It provides for Survey of street vendors and protection from eviction or relocation; issuance of a certificate for vending; provides for rights and obligations of street vendors; development of street vending plans; organizing of capacity building programmes to enable the street vendors to exercise the rights contemplated under this Act; undertake research, education and training programmes to advance knowledge and understanding of the role of the informal sector in the economy, in general, and the street vendors, in particular, and to raise awareness.

iv) The Scheduled Tribes and other Traditional Forest Dwellers (Recognition of Forest Rights)Act, 2006.

An Act to recognise and vest the forest rights and occupation in forest land in forest-dwelling Scheduled Tribes and other traditional forest dwellers who have been residing in such forests for generations but whose rights could not be recorded; to provide for a framework for recording the forests rights so vested and the nature of evidence required for such recognition and vesting in respect of forest land.

v) Right to Information (RTI) Act, 2005

The basic object of the Right to Information Act is to empower the citizens, promote transparency and accountability in the working of the Government, contain corruption, and make our democracy work for the people in real sense. It says that an informed citizen is better equipped to keep necessary vigil on the instruments of governance and make the government more accountable to the citizens.

vi) National Fisheries Policy (Draft) 2020

The policy aims at comprehensive development of the fisheries sector through appropriate interventions to address the critical gaps with an overarching goal for growths in exports, an increase in farmer's income and better choice for consumers. It aims for robust management and regulatory framework with necessary legal backing for effective fisheries resource management through an Ecosystem Approach of Fisheries (EAF) management within the overall framework of relevant national and international instruments, policies and standards. To generate gainful employment and entrepreneurship opportunities along the value chain leading to the higher income of fishers and fish farmers, improve their living standards and usher in economic prosperity.

vii) Tamil Nadu Marine Fishing Regulation Act 1983 (Amended in 2016)

An act to provide for the regulation, restriction and prohibition of fishing by fishing vessels in the sea along the whole or part of the coastline of the State

viii) The operational policy of the World Bank on Social Safeguard

- Indigenous People: This policy applies for both positive and negative impacts on tribal population wherever the project activities are undertaken. Accordingly, the policy creates scope to studied whether the project will have an impact on any individual or cluster of tribal people during any phase of the project.
- Involuntary Resettlement: Involuntary resettlement should be avoided where feasible, or minimized, exploring all viable alternative project designs. Where it is not feasible to avoid resettlement, resettlement activities should be conceived and executed as sustainable development programs, providing sufficient investment resources to enable the persons displaced by the project to share in project benefits. Displaced persons should be meaningfully consulted and should have opportunities to participate in planning and implementing resettlement programs. Displaced persons should be assisted in their efforts to improve their livelihoods and standards of living or at least to restore them, in real terms, to pre-displacement levels or to levels prevailing prior to the beginning of project implementation, whichever is higher.
- Policy on Access to Information and Disclosure: World Bank safeguards policy requires consultation with PAPs during planning and implementation of resettlement action plan and tribal development plan and public disclosure of drafts. Once the draft is prepared, it is to be made available at a place accessible to, and in a form, manner and language understandable to the displaced or affected people and local NGOs. RTFCTLARR, 2017 also requires disclosure of draft SIA and RAP and other project reports followed by mandatory Public Hearing. Consultations with PAPs or interested people, people in the vicinity of the project area is to be done and public disclosure on the project details, positive/negative social impacts and to get their feedback is to be carried out at appropriate intervals of the project period.

ix) ADB's Safeguard Policy

Safeguard policy statement (SPS) are generally operational policies that seek to avoid, minimize, or mitigate adverse environmental and social impacts, including protecting the rights of those likely to be affected or marginalized by the development process. ADB's safeguard policy framework consists of three operational policies on the Environment, Indigenous Peoples, and involuntary resettlement and brings them into a consolidated policy framework that enhances effectiveness and relevance. Accordingly,

i) impacts are to be identified and assessed early in the project cycle;

ii) plans to avoid, minimize, mitigate, or compensate for the potential adverse impacts are developed and implemented; and

iii) affected people are informed and consulted during project preparation and implementation.

Annex 1.4. Institutional Arrangements

Under overall direction, guidance and coordination of the CMWSSB Project Implementation Unit (PIU), the perspective contractor will implement Chennai Perur 400 MLS Desalination Plant. The Project Management Consultant (PMC) appointed by PIU comprises of the subject, and sector-specific specialists will provide onsite expert guidance as well as supervise the progress and attainment of drafted specified guidelines by the contractor in compliance to the regulatory mandates. Referring to the Social Management Plan (SMP) and implementation; Social Communication Specialists will be the interacting regular basis with the social specialist appointed by the contractor for social safeguard compliance.

Annexure 2 SALIENT FEATURES OF KEY APPLICABLE LABOUR LAWS

(the law/rules as current on the date of bid opening will apply)

1) Payment of Wages Act, 1936: It lays down as to by what date the wages are to be paid when it will be paid and what deductions can be made from the wages of the workers.
2) Minimum Wages Act, 1948: The employer is supposed to pay not less than the Minimum Wages fixed by appropriate Government as per provisions of the Act if the employee is scheduled employment. Construction of buildings, roads, runways etc. are scheduled employments.
3) The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 and the Cess Act of 1996: All the establishments who carry on any building or other construction work and employs 10 or more workers are covered under this Act. All such establishments are required to pay less at the rate not exceeding 2% of the cost of construction as may be modified by the Government. The Employer to whom the Act applies has to obtain a registration certificate from the Registering Officer appointed by the Government.
4) Inter-State Migrant Workmen's (Regulation of Employment & Conditions of Service) Act, 1979: The Act applies to an establishment which employs 5 or more inter-state migrant workmen through an intermediary (who has recruited workmen in one state for employment in the establishment situated in another state). The Inter-State migrant workmen, in an establishment to which this Act becomes applicable, are required to be provided certain facilities such as housing, medical aid, travelling expenses from home up to the establishment and back, etc.
5) Employees P.F. and Miscellaneous Provision Act, 1952: The Act provides for monthly contribution by the employer plus workers @ 10% or 8.33%. The benefits payable under the Act are:
   (i) Pension or family pension on retirement or death, as the case may be.
   (ii) Deposit linked insurance on the death in a harness of the worker.
   (iii) Payment of P.F. accumulation on retirement/death etc.
6) Employees Compensation Act, 1923: The Act provides for compensation in case of injury, disease or death arising out of and during employment by certain employers to their employees for injury caused to them by accident. It enables an employee, and in case of death of an employee, his dependents, to get, at the cost of his employer compensation for employment injury if an employee contracts an occupational disease while in employment, it is also treated

under the Act as injury caused by accident.

7) The Personal Injuries (Compensation Insurance) Act, 1963: This Act provides for the employer's liability and responsibility to pay compensation to employees where workmen sustain personal injuries in the course of employment. The employer has to provide workmen with the insurance against the liability. The Act describes the term which is of major importance under the Act is called as partial disablement and total disablement.

8) Employer's Liability Act, 1938: This Act protects workmen who bring suits for damages against employers in case of injuries endured in the course of employment. Such injuries could be on account of negligence on the part of the employer or persons employed by them in the maintenance of all machinery, equipment etc. in healthy and sound condition.

9) Employee's State Insurance Act, 1948: The Act provides for certain benefits to insured employees and their families in case of sickness, maternity and disablement arising out of an employment injury. The Act applies to all employees in factories (as defined) or establishments which may be so notified by the appropriate Government. The Act provides for the setting up of an Employees' State Insurance Fund, which is to be administered by the Employees State Insurance Corporation. Contributions to the Fund are paid by the employer and the employee at rates as prescribed by the Central Government. The Act also provides for benefits to dependents of insured persons in case of death as a result of an employment injury.

10) Payment of Bonus Act, 1965: The Act applies to all establishments employing 20 or more employees. The Act provides for payments of annual bonus subject to a minimum of 8.33% of the wages drawn in the relevant year. It applies to skilled or unskilled manual, supervisory, managerial, administrative, technical or clerical work for hire or reward to employees who draw a salary of Rs. 10,000/- per month or less. To be eligible for the bonus, the employee should have worked in the establishment for not less than 30 working days in the relevant year. The Act does not apply to certain establishments. The newly set-up establishments are exempted for five years in certain circumstances. Some of the State Governments have reduced the employment size from 20 to 10 for applicability of this Act.

11) Payment of Gratuity Act, 1972: Gratuity is payable to an employee under the Act on the satisfaction of certain conditions - on separation if an employee has completed 5 years of service or more or on death, the rate of 15 days wages for every completed year of service. The Act applies to all establishments employing 10 or more employees.

12) Labour (Regulation and Abolition) Act, 1970: The Act provides for certain welfare measures to be provided by the contractor to contract labour, and in case the Contractor fails to provide, the same is required to be provided, by the Principal Employer by Law. The Principal Employer is required to take Certificate of Registration, and the Contractor is required to take a license

from the designated Officer. The Act applies to the establishments or Contractor of Principal Employer if they employ 20 or more contract labour.

13) Equal Remuneration Act, 1979: The Act provides that no employer shall pay to any worker employed by him in an establishment or employment, remuneration whether payable in cash or in-kind at the rates less favourable than those at which remuneration is paid by him to the workers of the opposite sex in such establishment or employment. The Act further provides that no discrimination should be made against women at the time of recruitment. The Act also provides for not for making discrimination against female employees in the matters of transfers, training and promotions etc.

14) Maternity Benefit Act, 1951: An Act to regulate the employment of women in certain establishments for certain periods before and after child-birth and to provide for maternity benefit and certain other benefits. It provides for maternity benefits, including leave, wages, bonus, nursing breaks etc.

15) Sexual Harassment of Women at the Workplace (Prevention, Prohibition and Redressal) Act, 2013: This Act defines sexual harassment in the workplace, provides for an enquiry procedure in case of complaints and mandates the setting up of an Internal Complaints Committee or a Local Complaints Committee.

16) Child Labour (Prohibition and Regulation) Act, 1986: The Act prohibits employment of children below 14 years of age in certain occupations and processes and provides for the regulation of employment of children in all other occupations and processes. Employment of child labour is prohibited in the Building and Construction Industry.

17) Bonded Labour System (Abolition) Act, 1976: The Act provides for the abolition of bonded labour system with a view to preventing the economic and physical exploitation of weaker sections of society. Bonded labour covers all forms of forced labour, including that arising out of a loan, debt or advance.

17. SITE DATA

17.1 Topographical Survey Data

The topographic survey of the plant has been done. The topographic drawing 7061563-PMC400MLD-CP1-Topography-001 has been attached in the Part-2C. The land is slopping from the East Coast Road side at CD + 8.0 m to the seashore at CD + 2.0 to 3.0. Figure 1 below shows the land development plant for the Perur Plant.

17.1.1 **Foundation of the Structure and Building**

Figure 1 shows the plan of land development. Since the height of existing project site is CD + 2 to 3 m on the shoreside, earth filling by 4 m will be necessary to realize the ground elevation of CD +6.5 m in order to protect the plant in the event of strong wind and waves, Global Warming and Tsunami. The finished surface level (FSL) of the CD +7.0 is being proposed for the said plant. The equipment plinth levels should be not lower than +7.5 for the ease in operation.

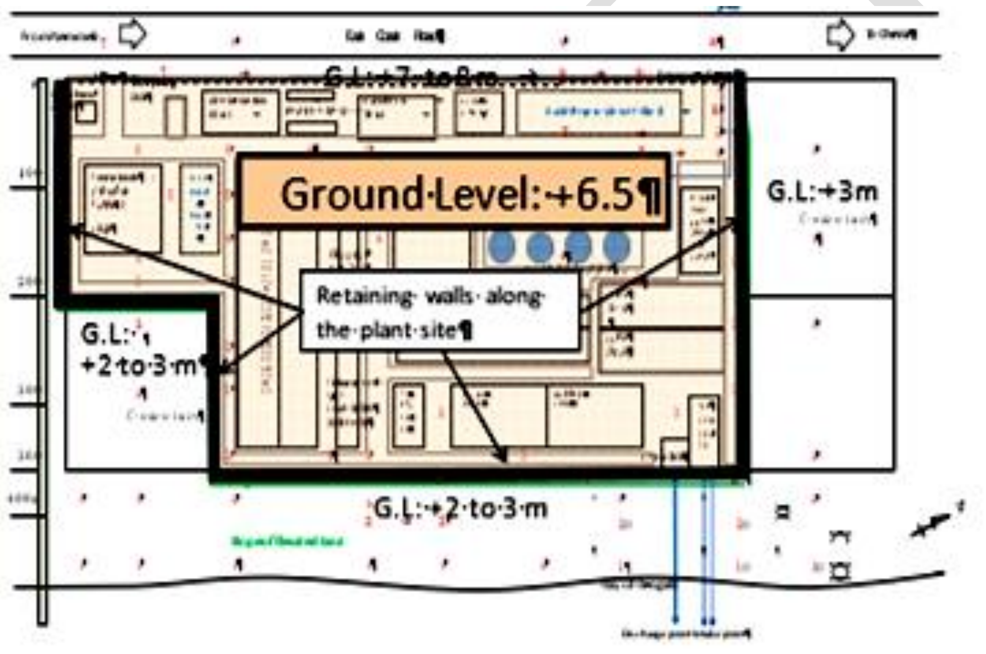

Figure 1: Land Development Plan of the Chennai Seawater Desalination Plant

The border of this newly constructed land and other areas will be retaining wall of reinforced concrete. Embankment is another alternative, but the sea wave may scour the foundation of the slope. The retaining wall with pile foundation will be more stable.

17.1.2 **Foundation of the Structure and Building**

Several treatment units for desalination and auxiliary buildings and structures will be constructed at the plant site. In the Study, maximum unit loads of such buildings and structures have been presumed referring similar projects. The surface soil layer in the plant site will be filled soils, which will be capable to bear the unit load not less than 10 kN/m2 by direct foundation. For the buildings and structures with the unit loads greater than 10 kN/m2, pile foundation will be necessary. The presumed pipe diameter in the Study is 400 mm, which is the most common diameter of cast-in-place reinforced concrete pile in Chennai. Pipe lengths should be planned so that the piles will be supported by Grayish Weathered Rock layer, with N values of more than 100, which was observed at the depth of 16.5 m from the present ground surface level. The geotechnical survey shall be conducted to verify the data. The intervals of the piles should be planned for the respective structures and buildings based on the unit loads, pile diameter and the bearing capacity of the supporting layer.

17.2 Environmental and Social Baseline Data

The Environmental baseline data extracted from the EIA report is furnished as below:

17.2.1 Ambient Air Quality

For the EIA study, ambient air quality monitoring surveys were carried out from March to May 2012 at eight locations set up in an area of 10 km radius around the proposed project site. The results of these surveys are summarized in Table 1.

Table 40: Ambient Air Quality around Proposed Project Site

Location	**PM_{10} (µg/m^3)**		**$PM_{2.5}$ (µg/m^3)**		**SO_2 (µg/m^3)**		**NO_x (µg/m^3)**		**CO (µg/m3)**	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
Near Plant Site	49.9	40.9	18.5	12.8	10.7	8.6	14.2	10.7	514	383
Thiruporur	51.5	42.4	19.5	13.8	10.8	8.2	13.6	11.0	527	390
Alathur	47.3	41.4	17.3	13.9	9.8	8.3	13.3	10.4	481	373
Pudunemmenl-kuppan	46.0	37.8	17.4	12.9	9.6	7.5	13.7	9.7	495	365
Thiruvidanthal	44.7	36.7	16.1	12.4	10.2	7.9	13.5	10.0	486	371
Kelambakkam	52.5	45.2	19.5	15.1	10.4	8.6	14.8	11.4	536	394
Nemmeli	40.0	32.7	14.6	11.0	9.9	8.2	13.8	10.2	489	368
Tandalam	43.6	36.3	15.4	11.8	9.8	8.2	13.1	10.4	497	377
Range	32.7-52.5		11.0-19.5		7.5-10.8		9.7-14.8		365-536	
Standards	**100**		**60**		**80**		**80**		**2,000**	

Based on the table, the EIA report concluded that the concentrations of the ambient air pollutants of PM_{10}, $PM_{2.5}$, SO_2, NO_x and CO were within the air quality standards for Industrial, Rural, Residential and Other areas of the Central Pollution Control Board (CPCB), National Ambient Air Quality Standards (NAAQS).

17.2.2 Water Quality

For the EIA study, ground and surface water quality monitoring surveys were carried out in 2012 at four and two locations, respectively, that were set up in an area of 10 km radius around the proposed project site, as shown in Table 2. The results of these surveys are summarized in Table 3.

Table 41: Water Quality Monitoring Location

		Location	Distance from Project Site (km)	Direction from Project Site
Ground water	GW1	Alathur	5.0	SW
	GW2	Thiruporur	4.7	MW
	GW3	Pudunemmelikuppam	1.9	SSW
	GW4	Thiruvidanthai	6.9	NNE
Surface Water	SW1	Pattipulam	2.7	SSW
	SW2	Vada Nemmeli	4.6	NNE

Table 42: Ground and Surface Water Quality around Proposed Project Site

Parameters	Unit	IS:10500 Limits	GW1	GW2	GW3	GW4	SW1	SW2
pH	-	6.5-8.5 (NR)	7.4	7.5	7.3	7.6	7.9	7.9
Color	Hazen	5 (25)	2	3	2	2	2	2
Taste	-	Agreeable	Ag	Ag	Ag	Ag	51,600	51,800
Odor	-	U.O	U.O	U.O	U.O	U.O	-	-
Conductivity	µS/cm	$	1,601	1,676	104	1,568	-	-
Turbidity	NTU	5 (10)	1	2	1	1	-	-
TDS	mg/l	500 (2000)	1,040	1,080	65	1,015	33,540	33,670
Total Hardness	mg/l	300 (600)	473	497	39	640	7,013	7,059
Total Alkalinity	mg/l	200 (600)	485	350	22	510	145	150
Calcium as Ca	mg/l	75 (200)	160.5	165	10.2	85	690	700
Magnesium as Mg	mg/l	30 (100)	17.5	20.5	5.3	40	1,285	1,290
Residual Chlorine	mg/l	0.2 Min	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	mg/l	1	0.01	0.02	<0.01	0.02	0.04	0.05
Chloride as Cl	mg/l	250 (1000)	140.2	235	10.2	85	17,359	17,458
Sulphate as SO_4	mg/l	200 (400)	86.5	112.2	6.1	120	0.1	650
Fluorides as F	mg/l	1.0 (1.5)	0.9	0.8	0.5	0.7	620	2
Nitrates as NO_3	mg/l	45 (NR)	30.2	35	11.2	36	2	3.5
Sodium as Na	mg/l	$	145	150	6.2	65	3	8524
Potassium as K	mg/l	$	15.6	16	0.6	14	8,500	350
Phenolic compounds	mg/l	0.001 (0.002)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Parameters	Unit	IS:10500 Limits	GW1	GW2	GW3	GW4	SW1	SW2
Cyanides	mg/l	0.05 (NR)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Anionic Detergents	mg/l	0.2 (1.0)	<0.1	<0.1	<0.1	<0.1	Absent	Absent
Mineral Oil	mg/l	0.01 (0.03)	<0.01	<0.01	<0.01	<0.01	-	-
Cadmium as Cd	mg/l	0.01 (NR)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic as As	mg/l	0.01 (NR)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper as Cu	mg/l	0.05 (1.5)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead as Pb	mg/l	0.05 (NR)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese as Mg	mg/l	0.1 (0.3)	0.01	0.04	<0.01	0.02	-	-
Iron as Fe	mg/l	0.3 (1.0)	0.06	0.04	0.02	0.05	0.03	0.03
Chromium as Cr^{+6}	mg/l	0.05 (NR)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium as Se	mg/l	0.01 (NR)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc as Zn	mg/l	5 (15)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aluminum as Al	mg/l	0.03 (0.2)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury as Hg	mg/l	0.001 (NR)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pesticides	mg/l	Absent	Absent	Absent	Absent	Absent	Absent	Absent
E. Coli	-	Absent	Absent	Absent	Absent	Absent	-	-
Total Coli forms	MPN/100	10	<2	<2	<2	<2	<2	<2
DO	mg/l	$	-	-	-	-	5.5	5.6
BOD	mg/l	$	-	-	-	-	<3	<3
COD	mg/l	$	-	-	-	-	<5	<5
Phosphates as PO_4	mg/l	$	-	-	-	-	0.1	0.1
Oil and Grease	mg/l	$	-	-	-	-	<1	<1
SAR	-	$	-	-	-	-	44.17	44.15

Note: Values in parenthesis are 'Permissible limit in the absence of Alternate source'. NR: No relaxation, $: Limits not specified, UO: Un-Objectionable, Ag-: Agreeable, SAR: Sodium Absorption Ratio

IS: 10500 (the standard prescribes the requirements for the essential and desirable characteristics required to be tested for ascertaining the suitability of water for drinking purpose)

According to the table, the ground water and surface water surveyed are discussed as follows:

- TDS (Total Dissolved Solid), Hardness ($CaCO_3$), Total Alkalinity and Calcium (Ca) showed higher values than the Indian Standard for safe drinking water of IS 10500 in the wells other than the GW3.

- TDS (Total Dissolved Solid), Hardness ($CaCO_3$), Calcium (Ca) and Magnesium (Mg) showed higher values than the Indian Standard for Safe Drinking Water of IS 10500 in both surface water and ground water.

17.2.3 **Soil Characteristics**

For the EIA study, soil samples were collected for analysis from eight locations of 10 km radius around the proposed project site as shown in Table 4; the results have been summarized as follows.

Table 43: Soil Quality Monitoring Location

	Location	Distance from Project Site (km)	Direction from Project Site
S1	Near- Plant Site	0.0	-
S2	Thiruporur	4.7	NW
S3	Aalathur	5.0	SW
S4	Pudunellikuppam	1.9	SSW
S5	Thiruvidanthal	6.9	NNE
S6	Kelambakkam	9.2	NNW
S7	Nemmeli	1.2	NW
S8	Thandalam	3.2	W

- pH of soil samples ranged from 7.8 to 8.1
- Electrical Conductivity (EC) of the soil samples varied from 144 to 280 μmhos/cm
- Phosphorus (P) values ranged between 28.2 kg/ha and 78.0 kg/ha
- Nitrogen (N) values ranged between 38.0 kg/ha and 65.0 kg/ha
- Potassium (K) values ranged between 0.06 kg/ha and 0.20 kg/ha

17.2.4 **Noise**

For the EIA study, noise levels were monitored at eight locations of 10 km radius around the proposed project site; the results have been summarized in Table 5.

Table 44: Noise Level around Proposed Project Site

	Location	Distance from Project Site (km)	Direction from Project Site	Zone	L_{10}	L_{50}	L_{90}	L_{eq}	L_{day}	L_{night}	L_{dn}
N1	Near- Plant Site	0.0	-	Residential	44.3	40.4	36.7	41.4	42.2	38.6	45.7
N2	Thiruporur	4.7	NW	Residential	47.7	43.8	40.1	44.8	45.6	42.0	49.1

N3	Aalathur	5.0	SW	Residential	45.8	41.9	38.2	42.9	43.7	40.1	47.2
N4	Pudunellikuppam	1.9	SSW	Residential	45.1	41.2	37.5	42.2	43.0	39.4	46.5
N5	Thiruvidanthal	6.9	NNE	Residential	46.2	42.3	38.6	43.3	44.1	40.5	47.6
N6	Kelambakkam	9.2	NNW	Residential	48.3	44.4	40.7	45.4	46.2	42.6	49.7
N7	Nemmeli	1.2	NW	Residential	45.5	41.6	37.9	42.6	43.4	39.8	46.9
N8	Thandalam	3.2	W	Residential	44.9	41.0	37.3	42.0	42.8	39.2	46.3

- The day-night noise level (Ldn) near the proposed project site was observed as 45.7 dB(A).
- The noise levels observed were within the acceptable levels as per the standards of Central Pollution Control Board (CPCB).

17.2.5 Turtle Nesting Areas

In Tamil Nadu, five species of sea turtles (Olive Ridley, Loggerhead Turtle, Hawksbill Turtle, Green Turtle and Leatherback Turtle) have been reported as follows.

- Olive Ridley (arribada) nests sporadically along northern Tamil Nadu coast and high nesting was observed along Nagapattinam and Chennai coasts.
- Olive Ridley is classified under Schedule I of the Wildlife Act of India.
- One such location is the Chennai coast between the Neelankarai-Napier Bridge stretch.
- The other turtle nesting areas are the coasts between Tranquebar and Pazhayaru, Mamallapuram and Chennai and Point Calimere and Nagapattinam.
- Turtle nesting was reported during December to February and also during April to June.
- Olive Ridleys nest along the Chennai coast between January and March.

17.2.6 Marine Environment

The marine (seashore and offshore) environment around the proposed project site and in Chennai coast have been summarized in the EIA report for the project as shown in Table 6.

Table 45: Marine Environment around the Proposed Project Site

Item	Description
Wind	• Wind speed varies between 7 to 11 knots throughout the year • During Apr., May, Jun. and Dec. the wind speed varies around 10-11 knots • During the remaining months, wind speeds vary between 7 and 9 knots. • During Apr. to Sept., the morning wind mostly prevailed from SW and W, and during Nov. to Feb., it mostly prevailed from NW.
Storm	• In total, 58 storms had crossed within 300 km from the project region, and the occurrence of storms in this region are more frequent in Oct. and in Nov.

Tide	• MHWS (Mean High Water Spring): 1.15m • MHWN (Mean High Water Neap): 0.84 m • MSL (Mean Sea Level): 0.65 m • MLWN (Mean Low Water Neap): 0.43 m • MLWS (Mean Low Water Spring) : 0.14 m
Current	• During the measurement period, the maximum current speed recorded was 0.33 m/s. • The current direction was shifting with tides showing the variation within the sector of 330°-90°.
Waves	• The significant wave height varies between 0.5 m and 1.0 m during Feb. to Apr. • Between 1m and 3 m during May to Sept. • Between 1m and 2 m during rest of the year • The zero crossing period of the waves varied between 5 s. and 8 s.
Temperature	• Between 27°C and 30°C throughout the year.
Littoral drift	• The sediment transport rates were high in May and Dec. and low in Mar. • The littoral drift was towards north from Apr. to Oct. and towards south during the remaining months of the year.
Seismic survey Result	• The shallow seismic study reveals that the sub-seabed consists of a sedimentary layer such as sand and clay up to few meters below the seabed. • The submerged and buried rocks are also noticed within the study region.
Side scan survey Result	• The analyzed records reveal that the seabed is generally covered by sandy clay, clayey sand, coarse sand with scattered rocky outcrops.

17.2.7 **Hydrology**

The proposed project site is located in the Kovalam sub-basin in the Chennai Basin between Adyar River and Palar River in the Chennai region. Administratively, the site is in the Chengalpattu District, which is located in the Chennai River Basin.

17.2.8 **Flora**

The project site area is widely dominated by Casuarina litorea trees and sparsely populated with Veelikkaruvai (Prospopis juliflora), Ipomea pes caprae, Pandanus odoratissimus, Catharanus rouseus, Thespesia populnea, Cocus nucifera, Borassus flabellifer, Azadirachta indica, Pedalium sp., Calotropis gigantean and Spinifex littoreus.

Especially, the front face of the site towards the sea face is fully planted with *Casuarina litorea* tree. Plantations were grown and maintained by the Department of Forest, Government of Tamil Nadu.

17.2.9 **Fauna**

Table 7 provides a list of critically endangered and endangered fauna species found in Tamil Nadu State.

Table 46: Critically Endangered and Endangered Fauna Species in Tamil Nadu State

Fauna		English Name	Scientific Name
Critically Endangered Species	Birds	Spoon Billed Sandpiper	*Eurynorhynchus pygmeus*
	Mammals	Large Rock Rat	*Cremnomys elvira*
	Reptiles	Hawksbill Turtle	*Eretmochelys imbricata*
	Amphibians	Anamalai Flying Frog	*Rhacophorus pseudomalabaricus*
		Kerala Indian Frog	*Indirana phrynoderma*
		Griet Bush Frog	*Raorchestes griet*
		Large Ponmudi Bush Frog	*Raorchestes ponmudi*
		Sushil's Bush Frog	*Raorchestes sushili*
	Fish	Pondicherry Shark	*Carcharhinus hemiodon*
Endangered Species	Mammals	Blackbuck	*Antilope cervicapra*
		Nilgiri langur	*Presbytis johni*
		Lion Tailed Macaque	*Macaca silenus*
		Nilgiri tahr	*Nilgiritragus hylocrius*
		Servant mouse	*Mus famulus*
		Salim Ali's Fruit Bat	*Latidens salimalii*
	Reptiles	Perrotet's Vine Snake	*Ahaetulla perroteti*
		Boulenger's Dasia	*Dasia subcaerulea*
		Indian Kangaroo Lizard	*Otocryptis beddomii*
		Travancore Hills Thorntail Snake	*Platyplectrurus madurensis*
		Tamil Nadu Earth Snake	*Rhinophis travancoricus*
	Fish	Aruli Barb	*Dawkinsia arulius*
		Tambraparini Barb	*Dawkinsia tambraparniei*
		Nilgiri Danio	*Devario neilgherriensis*
		Cardamon Garra	*Garra hughi*
		Kalakad Stone Carp	*Garra kalakadensis*
		Anamalai Sucker Catfish	*Glyptothorax anamalaiensis*
		ray-finned fish	*Glyptothorax housei*
		Zig Zag Sucker Fish	*Homaloptera montana*
		Lipped Algae Eater	*Horalabiosa joshuai*
		Curcuma barb	*Hypselobarbus curmuca*
		Nilgiri Barb	*Hypselobarbus dubius*
		Korhi barb	*Hypselobarbus micropogon*

Fauna		**English Name**	**Scientific Name**
		Hump Backed Mahseer	*Hypselobarbus mussullah*
		Broadfin Shark	*Lamiopsis temminckii*
		Chennai Sawfin Barb	*Pethia sharmai*
		Round Tailed Killer Catfish	*Pterocryptis wynaadensis*
		Nukta	*Schismatorhynchos nukta*
		Great Hammerhead	*Sphyrna mokarran*
		Black Mahseer	*Tor khudree*
		Malabar Mahseer	*Tor malabaricus*
	Spiders	Parambikulam Large Burrowing Spider	*Haploclastus kayi*
		Beautiful Parachute Spider	*Poecilotheria formosa*
		Reddish Parachute Spider	*Poecilotheria rufilata*

In addition, the small animals in the proposed project site identified by the EIA report are Dead shells of gastropod and bivalve molluscs are largely found washed on the shoreline.

17.2.10 Marine Biodiversity

The marine (seashore and offshore) biodiversity around the proposed project site and in Chennai coast have been summarized in the EIA report for the project as shown in Table 2.8

Table 47: Marine Biodiversity around the Proposed Project Site

Item	**Description**
Floral Diversity	• Varies from 21 to 29 species. • Most dominant species are: *Bacillariophyceae* (Diatoms) formed the major group followed by *Dinophyceae* (Dinoflagellates) and *Cyanophyceae* (blue-green algae). • Phytoplankton population analyzed at various stations showed that their numerical abundance varied from 68 to 103 nos./ml. • As many as 55 species of phytoplankton (net and unit samples put together) represented by 3 diverse groups namely, diatoms (43 species consisting of 34 centrales and 9 pennales), dinophyceans (11) and chlorophyceae (1). • There were relatively fewer (46) species in the unit samples.
Zooplankton	• Fluctuates from 38 to 44 species. • Zooplankton mostly consists of *Coryceas danae* (13.5% to 8.7%), *Paracalanus parvus* (7.2% to 2.0%), *Oithona brevicornis* (6.8% to 0.6%), *Coryceas catus* (6.8% to 1.8%) and Copepod stages (5.6% to 1.9%).

Benthos	• Benthic faunal population in an environment depends on the nature of the substratum and the organic matter content of the substratum. • Sediment characteristics are of coarse to medium sand, the numerical abundance of benthic fauna varied between 80 and 170 nos/m^2 mainly consisting of amphipods, polychaetes, bivalves and mysids. • Intertidal benthos: Numerical abundance varied between 30 to 75 nos/m^2. • Generally, in a project area without pollution/stress/disturbance, the Shannon diversity values and Margalef's richness indices are higher in the range of 2.5 to 3.5, whereas it is low in the project area-which can be attributed to nature of sediment-which is sand in the area.
Microbiology	• The study indicated that there is no microbiological pollution. • Bacterial densities were higher in the sediment samples than those in the water samples, which can be attributed to rich organic content in sediment and lesser residence time of microorganisms in the water than the sediments.
Turtles	• Observed during February and March 2012, and devoid of nesting during the Survey period (July 2013).

17.3 Meteorological Data and Tidal Data

17.3.1 Climatic conditions

Chennai features a tropical wet and dry climate. Chennai lies on the thermal equator and is also coastal, which prevents extreme variation in seasonal temperature. For most of the year, the weather is hot and humid. Typical meteorological data for Perur DSP is furnished in the Table below. Cyclones are more common in the Bay of Bengal, and the proposed Perur site is expected to be affected by cyclones by approximately 3 times per year. The details of Typical Meteorological data for Perur DSP site are furnished in Table-9 below:

Table 48:Typical Meteorological data for Perur DSP

Meteorological Parameters	Unit	Values
Mean Ambient temperature (min./ max.)	° C	24.5/ 33.5
Barometric pressure	K Pa	100.1/ 101.35
Relative humidity (min./ average/ max.)	%	57/ 70/ 83
Main wind direction		South westerly
Average Annual rainfall	mm	1200
Average rainfall during Northeast monsoon (June to September)	mm	440
Average rainfall during Southwest monsoon (October to December)	mm	760

Maximum rainfall within 24 hours	mm	346.6

17.3.2 Typical Ocean conditions

The oceanography of the region is influenced by 3 climatic conditions viz., southwest monsoon (June – September), northeast monsoon (Mid – October to Mid – March) and a fair-weather period (Mid -March to May). The coast is more influenced by the northeast monsoon than the other seasons. Wave action is high during the northeast monsoon and cyclonic period. The coastal current within a 5 km radius distance is greatly influenced by winds and tides. The near shore remains more dynamic and turbulent due to persistent action of seasonal wind, high waves and sea currents. The distribution of temperature and salinity indicates that the near shore water is well mixed without stratification. The influence of littoral drift is significant, and the annual net drift takes place in a northerly direction. The tide elevation at Perur with reference to Chart Datum (CD) is furnished in Table-10 below:

Table 49:Tidal Elevation at Perur

Tidal elevation	**Chart Datum (CD) in m**	**RL (m)**
Mean High water spring	1.15	RL 0.5
Mean High water neaps	0.84	RL 0.2
Mean Sea Level	0.65	RL 0.0
Mean low water neaps	0.43	RL -0.22
Mean low water spring	0.14	RL -0.51

Note: Onshore survey levels are recorded as above mean sea level. Hence, the mean high-water springs conversion of CD to MSL is 1.15 -0.65 m = RL 0.5.

17.4 Ground Investigation and Ground Condition Data (i.e. Geotechnical Data, Geological Data)

A preliminary geotechnical report is attached in Annexure-2D-1

17.5 Utility Records

The site is not inhibited and there is no utility available on ground.

17.6 Land Ownership Data

The proposed land for the desalination plant identified under survey number – 208/ 2B3 belonging to the M/s. Arulmigu Alavandar Nayakar Trust maintained by The Hindu Religious and Charitable Trust (HR & CT) Department, Government of Tamil Nadu (GoTN). The land is procured by CMWSSB on a long-term lease basis.

The details of the local site conditions are given below in Table 11.

Table 50:Details of local site conditions for the proposed DSP site

Particulars	Details
Site Location	District: Chengalpattu/ Taluk: Thiruporur/ Village: Perur
Site coordinates	12°42'44"N, 80°14'26"E
Nearest highway	State Highway SH 49, East Coast Road
Nearest railway station	Othivakkam railway station
Nearest Airport	Chennai Airport
Nearest town/ City	Chengalpattu, Pudupattinam, Tirukalukundram, Nandivaram-Guduvancheri
Archaeologically Important places	Mahabalipuram

Site photographs and Project location drawings are furnished in Section C. Drawings

17.7 Orders, Consents, Permits, Licenses and Compliance Requirements

The Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) has obtained the Coastal Zone Regulation (CRZ) Clearance from Ministry of Environment and Forest and Climate Change (MoEF &CC). CMWSSB will be responsible for obtaining necessary permits/ clearances from the State/Centre Regulatory agencies namely Coastal Regulation Zone (CRZ) Clearance, Consent to Establish from Tamil Nadu State Pollution Control Board (TNPCB) and Approval from Tamil Nadu Maritime Board (TNMB). Except the Consents/ Permits specifically indicated above, the Contractor shall be responsible for obtaining necessary permits/ clearances from the State/ Centre Regulatory agencies under the applicable laws namely Consent to Operate from TNPCB and others as applicable to the project and comply with all such requirements during the contract period.

17.8 As-Built Records of Existing Infrastructure

There is no existing infrastructure on the site.

17.9 Quality and Environmental, Health or Safety Systems to Apply

17.9.1.1 *Quality Assurance*

Policy

The Contractor shall apply the formal requirements of Quality Assurance to the design, supply, construction and maintenance of the Works. This shall be achieved through the implementation of a Quality System compliant with the requirements of BS 5750 or an equivalent International Standard.

Positive commitment to Quality Assurance shall be expressed in a formal policy statement given in the Contractor's Quality Manual.

Objectives

It shall be the stated aim of the Contractor to achieve and demonstrate the achievement of quality as expressed by `due care and diligence' of the design, supply, construction and maintenance of the Works as defined by the Employer's Requirements.

The criteria to define `due care and diligence' shall be explained in the Contractor's Quality Plan and shall embody all of the design, supply, construction and maintenance requirements of the Works.

Quality System

The Quality System shall be fully integrated for all of the Works.

This system will be defined by the organisational structure, responsibilities, activities, resources, and events that together demonstrate the capability of the Contractor to meet the stated quality requirements.

The Contractor shall ensure that all sub-contractors and sub-consultants establish quality systems and shall supply to the Employer such evidence as is necessary to demonstrate the effective implementation of a quality system in each sub-contractor or sub-consultant organisation.

The Quality System of the Contractor and of his sub-contractor and sub-consultants will be subject to periodic audits undertaken by the Engineer. The Engineer will give two weeks' notice of such audits that will involve a full assessment of the performance and efficiency of the Quality

System and will include review of the feedback and records derived from the Contractor's monitoring and internal reviews.

On a day-to-day basis the Contractor shall afford reasonable availability of staff and documentation for the Engineer to assess the implementation of the Quality System. The Contractor shall ensure that all relevant personnel and documentation are available for such audits.

Quality Plan

The implementation of the Quality System shall be through the establishment of a comprehensive Quality Plan issued to and approved by the Engineer.

The documented procedures shall include but not be limited to:

- Management Procedures;
- Design;
- Supply/ Procurement;
- Construction;
- Putting to work/ Commissioning/ Reliability Trial/ Performance Test; witnessing the test and review
- Operator Training and Maintenance;
- Interface Control;
- Quality Performance, Monitoring and Review.

There shall be procedures to control transmission of information across all interfaces both internally (that is, within the Contractor's Quality System) and externally. Those of the latter shall include all Statutory Bodies, Authorities and the Engineer.

Formal assessment of any non-compliance with the Quality Plan shall be achieved through periodic reviews undertaken by a team appointed by the Contractor. All deficiencies shall be recorded and appropriate corrective measures shall be assessed, within an appropriate timescale, through subsequent formal reviews undertaken by the Contractor.

Quality Feedback

The system shall include for the reporting back, recording and incorporation into the system of deficiencies and remedial measures to correct them noted during the control of the project.

17.9.1.2 *Environmental Protection*

The Contractor shall minimize, as far as is practically possible, the effects of all his and his Subcontractors' activities upon the environment and shall implement and monitor measures to prevent:

(a) Contamination of surfaces, ground, groundwater, surface water and rivers,

(b) Emissions to air, including smells, gases, smoke, and dust.

(c) Unsanitary or unsafe storage or discharge to drain, sewer and surface waters,

(d) Unsanitary or unsafe storage or discharge of solid wastes,

(e) Noise,

(f) Visual intrusion, and

(g) Excessive energy and water consumption.

These requirements shall be met through the constant and careful attention of the Contractor's management of all Site and off-site activities, and by instruction to all staff and labour in these matters.

The Contractor shall appoint an Environmental Control Manager for the Works, who shall be responsible for preparing an Environmental Management Plan and ensuring its implementation by the Contractor after obtaining approval of the Engineer.

Implementation shall include for monitoring and reporting on the results of the above measures. Monitoring reports shall be in writing and submitted on a monthly basis as part of the monthly report referred to above. The report shall include a listing and summary of daily monitoring results on all aspects listed above.

All potentially affected areas of the Site, other areas used for or affected by the works and all adjacent or affected waterways shall be monitored and, where instructed by the Engineer, tested.

The Environmental Management Plan (EMP) shall identify the potential environmental impacts from the various construction and operations and maintenance activities to be undertaken in the Contract and set out in detail the approach he will adopt in mitigating these environmental impacts to ensure that the residual impacts are minor and confined to a short period.

The EMP shall consider but not be limited to the following:

- The methods of materials delivery, storage, usage and disposal; equipment usage; and site activities to ensure they have minimal impact on the environment,
- Only environmentally safe products and practices shall be adopted in performing his works, and
- The Contractor shall comply with all of the statutes regarding environmental effects.

The EMP shall provide separate descriptions of its proposals for minimizing any adverse environmental impacts/effects during the construction phase and the subsequent operations and maintenance phase. The contractor to prepare a comprehensive Environmental Monitoring plan (EMoP) during construction and operation phase.

The EMP and EMoP shall be provided in draft form within 28 days from the Notice to Commence, and shall be updated from time to time by the Contractor as agreed or required by the Engineer to ensure the objectives of environmental protection are fully met.

17.9.1.3 *Safety*

The Contractor shall prepare a Safety Plan and submit the same to the Engineer for approval within 28 days of receiving the Notice to Commence.

The Safety Plan shall be followed at all times by the Contractor and shall contain adequate control measures, in accordance with the relevant protection of property and local laws and regulations as well as internationally accepted good practice, for the prevention of accidents, fires and public nuisance.

The Safety Plan shall be implemented properly and diligently throughout the execution of the Works and during the operations and maintenance period.

The Contractor's Safety Plan shall make safety provision for, among other things:

(a) Deep excavations and collapsing sides in trench excavations,
(b) Scaffolds and overhead working,
(c) Working in confined spaces,
(d) Working in water,
(e) Contractor's Equipment, especially cranes, heavy vehicles, etc.
(f) Hand held power tools,
(g) Electrical equipment, power connection
(h) Hazardous chemicals, gases and fuels,
(i) The use of protective clothing, and
(j) The provision of first aid facilities.

The Safety Plan shall be developed to ensure zero fatal accidents and zero hazardous incidents/occurrences in all construction works. The Safety Plan shall include descriptions of the company's standard policies and procedures regarding its site organization and procedures, methods and frequency of conducting safety audits at the Site(s), record keeping and reporting, providing safety training for its personnel (including subcontractors), issue and mandatory use of safety equipment, and details of the qualifications and experience of the Bidder's proposed safety officers to be deployed at the Site(s). The Contractor shall provide separate descriptions in its Safety Plan covering the construction phase and the subsequent operations and maintenance phase.

The Contractor shall appoint a Full Time English speaking Safety Manager for the Works having experience in this field, who shall be responsible for implementing the Safety Plan. He shall be supported by at least two safety officers who are qualified for such safety works.

The Contractor shall ensure that his staff and labour and his Subcontractors are all fully trained in and aware of good and safe working practices.

The Contractor shall ensure that all precautions are taken to safeguard the general public and construction/operating staff from any danger.

All temporary and partially completed works shall be protected by way of barriers, lights, notices and the like.

All excavations and the like are to be protected by barriers at all times and adequately illuminated at night.

Warning and diversion signs concerning roadwork shall be suitably placed to give motorists ample warning. During the movement of heavy vehicles across roads or onto roads, men, bearing red flags, shall be in attendance to warn other road users and to generally control traffic in a safe manner.

The Safety Plan shall also consider requirements for warning and protection for other risks including overhead and underground cables, pipes or obstructions, or voids, openings, pits and trenches. The Contractor shall ensure that all appropriate measures are implemented.

The Safety Plan shall include a policy statement signed by the CEO or equivalent authority of the Organization declaring that safety and loss prevention shall be given the highest practicable priority in all aspects of the Contract. The Safety Plan shall be updated as necessary to cover the activities to be undertaken for operations and maintenance.

17.9.2 Details of Any Risks or Hazards

The major risks anticipated in the desalination facility are Fire, explosion, toxic release and natural calamities like Cyclone, Flood, Earthquake and Tsunami. Fire would result from Storage vessels which stores chemicals. Explosion is another risk which primarily depends on the rate of which the energy is released. It could result in thermal effects, missile effects and injury to personnel. Toxic release of chemicals is another major risk where the release in form of gas or vapour can pose a major hazard if proper care is not taken into consideration. The risk due to toxic release primary depends on the duration of exposure which range from sudden exposure at high concentration to a prolonged exposure at lower concentration.

Natural disasters viz. cyclones striking the project area could not be ruled out. All equipment and buildings in the desalination facility are to be designed in such a way that withstands to maximum wind speed during cyclones. The storm surge of 1.3 m height has been predicted for a cyclonic wind speed of 180 kmph for this region. As the project area is required to be elevated and the impact may not be severe.

Although earthquake is not a regular phenomenon, the possibility of its occurrence cannot be ruled out. Earthquakes will pose a major risk to the equipments/ buildings and pipelines, life of personnel and environment. The effect of earthquake includes ground lateral displacement, ground shaking and ground uplift, ground uplift, ground settlement, soil liquefaction and fires.

The risk associated with flood are water entering the desalination facility/ process units, danger to life of operating personnel and outbreak of epidemic and other contagious diseases. Flood warning systems from the local meteorological department on flood warning and specific actions to be taken during those occasions are to be considered in the Disaster control preparedness plan.

The occurrence of a Tsunami along the Indian coast is an extremely rare event with a very low frequency of less than once in 500 years. No reliable historical records of occurrence of Tsunami events and their impact along the Indian coast are available because of its exceedingly rare nature. One worst Tsunami occurred on 26th December 2004 along the Tamilnadu coast and the destruction was more near the project region. The project region is located on the notified area of Tsunami impact, as the offshore tectonic plates are alive in Andaman Island. The presence of sand dunes (> 3 m) on the coast may to some extent dissipate the strength of tsunami but cannot totally protect from tsunami run up.

A detailed Disaster Control Preparedness Plan to be prepared by Contractor considering multidisciplinary approach by involving government agencies at Central and State level, Fire services, Civil defence, Medical, Police, Army, Voluntary organisations etc., This plan is required to provide guidance to stake holders to take appropriate action to prevent accidents involving hazardous substances and to mitigate adverse effects of accidents that do nevertheless occur. This plan should cover both Onsite Disaster management plan as well as Offsite Disaster management plan.

PART 2 - Section VI-5A-Technical Specifications

GENERAL SPECIFICATIONS FOR CIVIL WORKS

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5A.1 - SITE CLEARANCE (CLEARING AND GRUBBING)

5A.1.1. Scope

This work shall consist of cutting, removing and disposing of all materials such as trees, bushes, shrubs, stumps, roots, grass, weeds, top organic soil not exceeding 150 mm in thickness, rubbish etc., from the area of Works which in the opinion of the Engineer are unsuitable for incorporation in the Works, and such other areas as may be specified on the Drawings or by the Engineer. It shall include necessary excavation, backfilling of pits resulting from uprooting of trees and stumps to required compaction, handling, salvaging, and disposal of cleared materials. Clearing and grubbing shall be performed in advance of earthwork operations and in accordance with the requirements of these Specifications.

5A.1.2. Preservation of Property/Amenities

Trees, shrubs, any other plants, pole lines, fences, signs, monuments, buildings, pipelines, sewers and all facilities within or adjacent to the site which are not to be disturbed shall be protected from injury or damage. The Contractor shall provide and install at his own expense, suitable safeguards approved by the Engineer for this purpose.

During clearing and grubbing, the Contractor shall take all adequate precautions against soil erosion, water pollution, etc., and where required, undertake additional Works to that effect vide relevant Clauses of section 3 Before start of operations, the Contractor shall submit to the Engineer for approval, his work plan including the procedure to be followed for disposal of waste materials, etc., and the schedules for carrying out temporary and permanent erosion control Works as stipulated in section 3.

5A.1.3. Methods, Tools and Equipment

Only such methods, tools and equipment as are approved by the Engineer and which will not affect the property to be preserved shall be adopted for the Work. If the area has thick vegetation / roots / trees, a crawler or pneumatic type dozer of adequate capacity may be used for clearance purposes. The dozer shall have ripper attachments for removal of tree stumps. All trees, stumps, etc., falling within excavation and fill lines shall be cut to such depth below ground level that in no case these fall within 500 mm of the sub-grade / foundation / bed level. Also, all vegetation such as roots, under-growths, grass and other deleterious matter unsuitable for incorporation in the Work shall be removed between fill lines to the satisfaction of the Engineer. On the areas beyond these limits, trees and stumps required to be removed as directed by the Engineer shall be cut down to 1 m below ground level so that these do not present any unsightly appearance. All branches of trees extending above the roadway shall be trimmed as directed by the Engineer.

All excavations below the general ground level arising out of the removal of trees, stumps, etc., shall be filled with suitable material and compacted thoroughly so as to make the surface as these points conform to the surrounding area. Ant-hills both above and below the ground, as are liable to collapse and obstruct free subsoil water flow shall be removed and their workings, which may extend to several meters, shall be suitably treated.

5A.1.4. Disposal of Materials

All materials arising from clearing and grubbing operations shall be the property of Employer and shall be disposed of by the Contractor as hereinafter provided or directed by the Engineer.

Trunks and stumps of trees shall be cleaned of limbs and roots and stacked. Also boulders, stones and other materials usable in construction shall be neatly stacked as directed by the Engineer. Stacking stumps, boulders, stones etc., shall be done at specified spots with all lifts and lead.

All products of clearing and grubbing which, in the opinion of the Engineer, cannot be used or auctioned shall be cleared away from the site in a manner as directed by the Engineer. Care shall be taken to see that unsuitable waste materials are disposed off in such a manner that there is no likelihood of these getting mixed up with the materials meant for construction.

Chapter – 5A.2

5A.2 - DISMANTLING AND DEMOLITION

5A.2.1. Scope

This work shall consist of removing, as hereinafter set forth, existing buildings, roofs, ceiling, flooring and paving, concrete and brick roofs and suspended floors, walls and columns, reinforced concrete and brick work, partitions, wood work, steel and iron work, doors and windows, pipes and sewer lines, posts or struts, fencing wire mesh, glazing, culverts, bridges, pavements, curbs and other structures like guard-rails, utility services, catch basins, inlets, etc., which are in place but interfere with the new construction or are not suitable to remain in place, and of salvaging and disposing of the resulting materials and back filling the resulting trenches and pits. Existing culverts, bridges, pavements and other structures which are within the highway and which are designated for removal, shall be removed up to the limits and extent specified in the Drawings or as indicated by the Engineer. Dismantling and removal operations shall be carried out with such equipment and in such a manner as to leave undisturbed, adjacent pavement, structures and any other work to be left in place. All operations necessary for the removal of any existing structure which might endanger new construction shall be completed prior to the start of new work.

5A.2.2. Applicable Codes

IS: 1200-1974 (Part: XVIII)	Method of Measurements of Building and Civil Engineering Works. Demolition and Dismantling (Reaffirmed 1992) (3rd Revision).
IS: 4130-1991	Demolition of Buildings - Code of Safety (2nd Revision).

5A.2.3. Terminology

The term ‘Dismantling’ implies carefully separating the parts without damage and removing. This may consist of dismantling one or more parts of the structure as specified or shown on the Drawings. The term ‘Demolition’ implies breaking up. This shall consist of demolishing whole or part of work including all relevant items as specified or shown on the Drawings.

5A.2.4. Buildings

5A.2.4.1 Precautions

All materials obtained from dismantling or demolition shall be the property of the Employer unless otherwise specified and shall be kept in safe custody until they are handed over to the Engineer. The demolition shall always be well planned before hand and shall generally be done in reverse order of the one in which the structure was constructed. The operations shall be got approved from the Engineer-In-Charge before starting the work.

Due care shall be taken to maintain the safety measures prescribed in IS: 4130. Necessary propping, shoring and or under pinning shall be provided to ensure the safety of the adjoining work or property before dismantling and demolishing is taken up and the work shall be carried out in such a way that no damage is caused to the adjoining work or property. Wherever specified, temporary enclosures or partitions shall also be provided, as directed by the Engineer. Necessary precautions shall be taken to keep down the dust nuisance to the minimum. Dismantling shall be done in a systemic manner. All materials which are likely to be damaged by dropping from a height or by demolishing roofs, masonry etc. shall be carefully removed first. The dismantled articles shall be removed manually or otherwise, lowered to the ground (and not thrown) and then properly stacked as directed by the Engineer. Where existing fixing is done by nails, screws, bolts, rivets, etc., dismantling shall be done by taking out the fixing with proper tools and not by tearing or ripping off. Any serviceable material, obtained during dismantling or demolition, shall be separated out and stacked properly as directed by the Engineer within a lead of 50 m. All unserviceable materials rubbish etc. shall be disposed off as directed by the Engineer. The Contractor shall maintain / disconnect existing services, whether temporary or permanent, where required by the Engineer.

5A.2.4.2 Measurements

All work shall be measured net in the decimal system, as fixed in its place, subject to the following limits, unless otherwise stated hereinafter.

1. Dimensions shall be measured correct to a cm.
2. Areas shall be worked out in sq mt correct to two places of decimal.
3. Cubical contents shall be worked out to the nearest 0.01 cum.

Parts of work required to be dismantled and those required to be demolished shall be measured separately. Measurements of all works except hidden work shall be taken before demolition or dismantling and no allowance for increase in bulk shall be allowed. Specifications for deduction for voids, openings etc. shall be on the same basis as that adopted for new construction of the work.

Work executed in the following conditions shall be measured separately:

1. Work in or under water and / or liquid mud;
2. Work in or under foul position.

5A.2.4.3 Rates

The rate shall include the cost of all labour involved and tools used in demolishing and dismantling including scaffolding. The rate shall also include the charges for separating out and stacking the serviceable material properly and disposing off unserviceable material within a distance of 50 m. The rate shall also include for temporary shoring for the safety of portions not required to be pulled down, or of adjoining property, and providing temporary enclosures or partitions, where considered necessary.

5A.2.5. Roofs

Roof coverings generally including battens boarding, mats, bamboo jaffari or other subsidiary supports shall be measured in sq mt except lead sheet roof covering, which shall be measured in tonnes and stone slab roof covering which shall be measured in cum. Ridges, hips and valleys shall be girthed and included with the roof area. Corrugated or semi corrugated surfaces shall be measured flat and not girthed. Mud phuska on roofs shall be measured in cum. Lead sheets in roofs shall be measured in tonnes and hips, valleys, flashings, lining to gutter etc. shall be included in this weight. R.B. or R.C.C. roofs shall be measured in cum and if reinforcement is required to be salvaged, it shall be so stated. When reinforcement is required to be separated, scraped and cleaned, the work shall be measured separately as tonnes of salvaged steel. Supporting members, such as rafters, purlins, beams joists, trusses etc. where of wood shall be measured in cum and steel or iron sections in tonnes.

5A.2.6. Ceiling

The stripping of ceilings shall be measured in sqm. Dismantling of supporting joists, beams, etc. shall be measured in cum or in tonnes. Height above floor levels if it exceeds 3.5 m shall paid for separately.

5A.2.7. Flooring and Paving

Dismantling of floors (except concrete and brick floors) shall be measured in sqm. Supports such as joints, beams etc. if any shall be measured as per Clause 5A.2.5.6. Concrete and bricks paving shall be measured as per Clause 5A.2.8.

5A.2.8. Concrete and Brick Roofs and Suspended Floors

Demolition of floors and roofs of concrete or brick shall be measured in cum. Beams cantilevers or other subsidiary supports of similar materials shall be included in the item. In measuring thickness of roofs provided with water proofing treatments with bitumen, felts, the thickness of water proofing treatment shall be ignored.

5A.2.9. Walls and Piers

Taking down walls and independent piers or columns of brick, stone or concrete shall be measured, in cum. All copings, corbels, cornices and other projections shall be included with the wall measurements. In measuring thickness of plastered walls, the thickness of plaster shall be ignored. Ashlar face stones, dressed stone work, precast concrete articles, etc. if required to be taken down intact shall be so stated, and measured separately in cum. Cleaning bricks stacking for measurements including all extra handling and removal and disposing off the rubbish as stated shall be enumerated in thousand of cleaned bricks. Cleaning stone obtained from demolished / dismantling stone masonry of any description including ashlar facing dressed stone work, stone slabs or flagging and precast concrete blocks including all extra handling and disposing of the rubbish as stated shall be measured in cum of cleaned stone. Honey comb works or cavity walls of bricks stone or concrete shall be measured as solid.

5A.2.10. Reinforced Concrete and Brick Work

Reinforced concrete structures and reinforced brick roof and walls shall be measured in cum and if reinforcement is required to be salvaged, it shall be so stated. Where reinforcement is required to be separated, scraped and cleaned, the work shall be measured separately in tonnes of salvaged steel.

5A.2.11. Partitions, Trellis Work, Etc.

Partitions or light walls of lath and plaster, trellis work, expanded metal, thin concrete or terracotta slabs and other similar materials including frame work if any shall be measured in sqm stating the over all thickness.

5A.2.12. Wood Work

All wood work including karries average 40 sq cm or over in section, shall be measured in cum, while that under 40 sq cm in section, in running metres. Ballies shall be measured in running metres. Boarding including wooden chajjas and sun shades along with supports shall be measured in square m in its plane.

5A.2.13. Steel and Iron Work

All steel and iron work shall be measured in tonnes. The weight shall be computed from standard tables unless the actual weight can readily be determined. Riveted work, where rivets are required to be cut, shall be measured separately. Marking of structural steel required to be re-erected shall be measured separately. In framed steel items, the weight or any covering material or filling such as iron sheets and expanded metal shall be included in the weight of the main article unless such covering is not ordered to be taken out separately.

5A.2.14. Doors and Windows

Dismantling of doors, windows, clerestory windows, ventilators etc. (Wood or metal) whether done separately or along with removal of wall by making recess in the wall shall be enumerated. Those exceeding 3 sqm each in area shall be measured separately. The item shall include removal of chowkhats architraves, hold fasts and other attachments. If only shutters are to be taken out it shall be measured separately.

5A.2.15. Pipes and Sewer Lines

Water pipe lines including rain water pipes with clamps and specials, sewer lines (salt glazed ware or concrete) etc. shall be described by their diameter and length measured in running m inclusive of joints. If the joints, special and fittings etc. are required to be separated, it shall be so stated and enumerated. Pucca drains shall be measured under relevant items. Value cistern, public fountain platform, fire hydrants, etc. shall be enumerated. Manholes and inspection chambers shall be enumerated stating the size and depth of manhole/inspection chamber. They shall be classified into different groups depending upon the depth, in unit of half and one m depth. The depth of the manhole shall be the distance between the top of manhole cover and invert level of the drain. Ventilating shafts, gully traps, flushing cisterns and other appurtenant items of work shall be enumerated.

5A.2.16. Posts or Struts

Posts or struts (wood, steel or RCC) section including taking out embedded portion shall be measured in running m.

5A.2.17. Fencing Wire Mesh

Wire mesh fencing of any type with frame shall be measured in square m.

5A.2.18. Glazing

Taking out any portion of serviceable glass except polished plate, from old sashes, skylights, etc. (any thickness, weight or size) raking out old putty, etc. shall be measured in square m. Irregular or circular panes shall be measured as rectangle or square enveloping the same, the width and height being measured correct to the nearest 0.5 cm.

5A.2.19. Dismantling Culverts, Bridges and Other Structures/Pavements

5A.2.19.1 Dismantling Culverts and Bridges

The structures shall be dismantled carefully and the resulting materials so removed as not to cause any damage to the serviceable materials to be salvaged, the part of the structure to be retained and any other properties or structures nearby. Unless otherwise specified, the superstructure portion of culverts / bridges shall be entirely removed and other parts removed below the ground level or as necessary depending upon the interference they cause to the new construction. Removal of overlaying or adjacent material, if required in connection with the dismantling of the structures shall be incidental to this item.

Where existing culvert / bridges are to be extended or otherwise incorporated in the new work, only such part or parts of the exiting structure shall be removed as are necessary and directed by the Engineer to provide a proper connection to the new work. The connecting edges shall be cut, chipped and trimmed to the required lines and grades without weakening or damaging any part of the structure to be retained. Due care should be taken to ensure that reinforcing bars which are to be left in place to project into the new work as dowels or ties are not injured during removal of concrete. Pipe culverts shall be carefully removed in such manner as to avoid damage to the pipes.

Steel structures shall, unless otherwise provided, be carefully dismantled in such a manner as to avoid damage to members thereof. If specified in the Drawings or directed by the Engineer that the structure is to be removed in a condition suitable for re-erection, all members shall be match-marked by the Contractor with white lead paint before dismantling; end pins, nuts, loose plates, etc., shall be similarly marked to indicate their proper location; all pins, pin holes and machined surfaces shall be painted with a mixture of white lead and tallow and all loose parts shall be securely wired to adjacent members or packed in boxes. Timber structures shall be removed in such a manner as to avoid damage to such timber or lumber when designated by the Engineer to be salvaged.

5A.2.19.2 Dismantling Pavements and Other Structures

In removing pavements, curbs, gutters and other structures like guard-rails, fences, manholes, catch-basins, inlets, etc. where portions of the existing construction are to be left in the finished work, the same shall be removed to an existing joint or cut and chipped to a true line with a face perpendicular to the surface of the existing structure. Sufficient removal shall be made to provide for proper grades and connections with the new work as directed by the Engineer. All concrete pavements, base courses in carriageway and shoulders etc., designated for removal shall broken to pieces whose volume shall not exceed 0.02 cum and stockpiled at designated locations if the material is to be used later or otherwise arranged for disposal as directed (see Clause 2.19.4).

5A.2.19.3 Back-filling

Holes and depressions caused by dismantling operations shall be backfilled with excavated or other approved materials and compacted to required density as directed by the Engineer.

5A.2.19.4 Disposal of Materials

All materials obtained by dismantling shall be the property of Employer. Unless otherwise specified, materials having any salvage value shall be placed in neat stacks of like materials within the right-of-way, as directed by the Engineer with all lifts and up to a lead of 1000 m. Pipe culverts that are removed shall be cleaned and neatly piled on the right-of-way at points designated by the Engineer with all lifts and lead up to 1000 m. Structural steel removed from old structures shall, unless otherwise specified or directed, be stored in a neat and presentable manner on blocks in locations suitable for loading. Structures or portions thereof which are specified in the Contract for re-erection shall be stored in separate piles. Timber or lumber from old structures which is designated by the Engineer as materials to be salvaged shall have all nails and bolts removed there from and shall be stored in neat piles in locations suitable for loading. All materials obtained from dismantling operations which, in the opinion of the Engineer, cannot be used or auctioned shall be disposed of as directed by the Engineer with all lifts and up to a lead of 1000 m.

Chapter – 5A.3

5A.3 -EARTHWORKS

5A.3.1. Applicable Codes

The following Indian Standard Codes, unless otherwise specified herein, shall be applicable. In all cases, the latest revision of the codes shall be referred to.

a) IS 783 - 1985 - Code of practice for laying of concrete pipes.

b) IS 3764 - 1992 - Excavation work - Code of Safety.

c) IS 2720 - Methods of test for soils:

(Part-1) - 1983 - Preparation of dry soil samples for various tests.

(Part-2) - 1973 - Determination of Water Content.

(Part-4) - 1985 - Grain size analysis.

(Part-5) - 1985 - Determination of liquid and plastic limit.

(Part-7) - 1980 - Determination of water content - dry density relation using light compaction.

(Part-9) - 1992 - Determination of dry density - moisture content by constant weight of soil method.

(Part-14) - 1983 - Determination of density index (relative density) Cohesionless soils.

(Part-22) - 1972 - Determination of organic matter.

(Part-26) - 1987 - Determination of pH Value.

(Part-27) - 1987 - Determination of total soluble sulphates.

(Part-28) - 1974 - Determination of dry density of soils in place, by the sand replacement method.

(Part-33) - 1971 - Determination of the density in place by the ring and water replacement method.

(Part-34) - 1972 - Determination of density of soil in place by rubber baloon method.

(Part-38) - 1976 - Compaction control test (Hilf Method).

5A.3.2. Drawings

Engineer will furnish drawings wherever, in his opinion, such drawings are required to show areas to be excavated/filled grade level, sequence of priorities etc. Contractor shall follow strictly such drawings.

5A.3.3. General

The Contractor shall furnish all tools, plant, instruments, qualified supervisory personnel, labour, materials, any temporary works, consumables, any and everything necessary, whether or not such items are specifically stated herein for completion of the work in accordance with the Specifications.

The Contractor shall survey the site before excavation and set out all lines and establish levels for various works such as grading, basement, foundations, plinth filling, roads, drains, cable trenches, pipelines etc. Such survey shall be carried out by taking accurate cross sections of the area perpendicular to established reference/grid lines at 8m intervals or nearer, if necessary, based on ground profile and thereafter properly recorded.

The excavation shall be carried out to correct lines and levels. This shall also include, where required, proper shoring to maintain excavations and also the furnishing, erecting and maintaining of substantial barricades around excavated areas and warning lamps at night.

The rates quoted shall also include for dumping of excavated material in regular heaps, bunds, riprap with regular slopes within the lead specified and leveling the same so as to provide natural drainage. Rock/soil excavated shall be stacked properly as approved by the Engineer. As a rule, all softer material shall be laid along the center of heaps, the harder and more weather resisting materials forming the casing on the sides and the top. Rock shall be stacked separately.

Topsoil shall be stock piled separately for later re-use.

5A.3.4. Clearing

The area to be excavated/filled shall be cleared of fences, trees, plants, logs, stumps, bush, vegetation, rubbish, slush, etc. and other objectionable matter. If any roots or stumps of trees are encountered during excavation, they shall also be removed. The material so removed shall be disposed off as approved by the Engineer. Where earth fill is intended, the area shall be stripped of all loose/ soft patches, top soil containing objectionable matter/ materials before fill commences.

5A.3.5. Classification

All materials to be excavated shall be classified by Engineer, into one of the following classes and shall be paid for at the rate tendered for that particular class of material. No distinction shall be made whether the material is dry, moist or wet. The decision of Engineer regarding the classification of the material shall be final and binding on Contractor and not be a subject matter of any appeal or arbitration.

Any earthwork will be classified under any of the following categories:

5A.3.5.1 Ordinary & Hard Soils

These shall include all kinds of soils containing kankar, sand, silt, moorum and/or shingle, gravel, clay, loam, peat, ash, shale, etc., which can generally be excavated by spade, pick axes and shovel, and which is not classified under “soft and decomposed rock” and “hard rock” defined below. This shall also include embedded rock boulders not longer than 1 metre in any one direction and not more than 200 mm in any one of the other two directions.

5A.3.5.2 Soft and Decomposed Rock

This shall include rock, boulders, slag, chalk, slate, hard mica schist, laterite, highly weathered granite gneiss and all other materials which in the opinion of Engineer is rock, but does not need blasting and could be removed readily with picks, hammer, crow bars, wedges, and pneumatic breaking equipment. The mere fact that Contractor resorts to blasting for reasons of his own, shall not qualify for classification under ‘hard rock’.

This shall also include excavation in macadam and tarred roads and pavements. This shall also include rock boulders not longer than 1 metre in any direction and not more than 500 mm in any one of the other two directions. Masonry to be dismantled will also be measured under this item.

5A.3.5.3 Hard Rock

This shall include all rock occurring in large continuous masses which cannot be removed except by blasting, chiselling or by drilling with heavy mechanical breakers. Harder varieties of rock with or without veins and secondary minerals which, in the opinion of Engineer require blasting shall be considered as hard rock. Boulders of rock occurring in such sizes and not classified under (a) and (b) above shall also be classified as hard rock. Concrete work both reinforced and unreinforced to be dismantled will be measured under this item, unless a separate provision is made in the Schedule of Quantities.

Before classification of material as rock the Contractor shall demonstrate to the satisfaction of the Employer’s Representative his inability to excavate it without resort to heavy percussion tools complete with rock bits, hydraulic wedges or blasting. Excavation by the use of explosive will not normally be permitted.

Material shall not be classified as rock unless the Employer’s Representative has agreed to such classification on the basis of such a demonstration before its excavation. Excavations where rock has been encountered and classified as such shall not be backfilled before examination of the excavated faces by the Employer’s Representative to enable the extent of the rock excavation to be determined.

5A.3.6. Excavation

All excavation work shall be carried out by mechanical equipment unless, in the opinion of Engineer, the work involved requires it to be carried out by manual methods.

Excavation for permanent work shall be taken out to such widths, lengths, depths and profiles are as shown on the drawings provided by the Contractor or such other lines and grades as may be agreed with the Engineer. Rough excavation shall be carried out to a depth of 150mm above the final level. The balance shall be excavated with special care. Soft pockets shall be removed below the final level and extra excavation filled up with lean concrete of grade M10 with 40 mm downgraded aggregates as approved by the Engineer. The final excavation should be carried out just prior to laying the blinding course.

Contractor may, for facility of work or similar other reasons excavate, and also backfill later, if so approved by Engineer, at his own cost outside the lines shown on the drawings or directed by Engineer. Should any excavation be taken below the specified elevations, Contractor shall fill it up, with concrete of the same class as in the foundation resting thereon, upto the required elevation. No extra shall be claimed by Contractor on this account.

All excavations shall be to the minimum dimensions required for safety and ease of working. Prior approval of the Engineer shall be obtained by the Contractor in each individual case, for the method proposed for the excavation, including dimensions, side slopes, dewatering, disposal, etc. This approval shall not in any way relieve the Contractor of his responsibility for any consequent loss or damage. The excavation must be carried out in the most expeditious and efficient manner. Side slopes shall be as steep as will stand safely for the actual soil conditions encountered. Every precaution shall be taken to prevent slips. Should slips occur, the slipped material shall be removed and the slope dressed to a modified stable slope. Removal of the slipped earth will not be paid for if the slips are due to the negligence of Contractor.

5A.3.7. Stripping Loose Rock

All loose boulders, detached rocks partially and other loose material which might move therewith not directly in the excavation but so close to the area to be excavated as to be liable, in the opinion of Engineer, to fall or otherwise endanger the workmen, equipment, or the work shall be stripped off and removed from the area of the excavation. The method used shall be such as not to render unstable or unsafe the portion which was originally sound and safe.

Any material not requiring removal in order to complete the permanent works, but which, in the opinion of Engineer, is likely to become loose or unstable later, shall also be promptly and satisfactorily removed. The cost of such stripping will be paid for at the unit rates accepted for the class of materials in question.

5A.3.8. Excavation in Hard Rock

5A.3.8.1 General Requirements

Unless otherwise stated herein, I.S. Specification "IS- 4081(1986) Safety code for Blasting and related Drilling Operations" shall be followed. After removal of overburden, if any, excavation shall be continued in rock to such widths, lengths, depths and profiles as are shown on the drawings or such other lines and grades as may be specified by the Engineer. As far as possible all blasting shall be completed prior to commencement of construction. At all stages of excavation, precautions shall be taken to preserve the rock below and beyond the lines specified for the excavation, in the soundest possible condition. The quantity and strength of explosive used, shall be such as will neither damage nor crack the rock outside the limits of excavation. All precautions, as directed by the Engineer, shall be taken during the blasting operations and care shall be taken that no damage is caused to adjoining buildings or structure as a result of blasting operations. In case of damage to permanent or temporary structures, Contractor shall repair the same to the satisfaction of the Engineer at his cost. As excavation approaches its final lines and levels, the depth of the charge holes and amount of explosives used shall be progressively and suitably reduced.

Specific permission of the Engineer will have to be taken by Contractor for blasting rock and he shall also obtain a valid Blasting License from the authorities concerned. If permission for blasting is refused by the Engineer, the rock shall be removed by wedging, pick, barring, heating and quenching or other approved means. All loose or loosened rock in the sides shall be removed by barring, wedging, etc. The unit rate for excavation in hard rock shall include the cost of all these operations.

Contractor shall obtain necessary license for storage of explosives, fuses and detonators issued to him from Employer's stores or from supplier arranged by him, from the authorities dealing with explosives. The fees, if any, required for obtaining such license, shall be borne by Contractor. Contractor shall have to make necessary storage facilities for the explosives etc. as per rules of local, State and Central Government authorities and Statutory bodies/regulations. Explosives shall be kept dry and shall not be exposed to direct rays of sun or be stored in the vicinity of fire, stoves, steam pipes or heated metal, etc. No explosive shall be brought near the work in excess of quantity required for a particular amount of firing to be done; and surplus left after filling the holes shall be removed to the magazine. The magazine shall be built as for as possible away from the area to be blasted, Engineer's prior approval shall be taken for the location proposed for the magazine.

In no case shall blasting be allowed closer than 30 metres to any structure or to locations where concrete has just been placed. In the latter case the concrete must be at least 7 days old.

In the case of water transmission, pipe lines works etc for water transfer, the following stipulations shall over-ride the corresponding stipulations in “General Requirements” given above:

Excavation in hard rock shall be only by chiseling / Jack hammering or by drilling with mechanical brakers.

The rock shall be removed by wedging, pick, boring, heating and quenching or other approved non-blasting methods. All loose or loosened rock in the sides shall be removed by barring, wedging etc. The unit rate for excavation in hard rock shall include the cost of all these operations. No blasting is allowed.

5A.3.8.2 Specific Requirements

For blasting operations, the following points shall be observed.

Contractor shall employ a competent and experienced supervisor and licensed blaster in-charge of each set of operation, who shall be held personally responsible to ensure that all safety regulations are carried out.

Before any blasting is carried out, Contractor shall intimate Engineer and obtain his approval in writing for resorting to such operations. He shall intimate the hours of firing charges, the nature of explosive to be used and the precautions taken for ensuring safety.

Contractor shall ensure that all workmen and the personnel at site are excluded from a area within 200 m. radius from the firing point, at least 5 minutes before firing time by sounding warning whistle. The area shall also be given warning by sounding a distinguishing whistle.

The blasting of rock near any existing buildings, equipment or any other property shall be done under cover if permitted by the Engineer and Contractor has to make all such necessary muffling arrangements. Covering may preferably be done by M.S. plates with adequate dead weight over them. Blasting shall be done with small charges only and where directed by Engineer, a trench shall have to be cut by chiseling prior to the blasting operation separating the area under blasting from the existing structures.

The firing shall be supervised by a Supervisor and not more than 6 (six) holes at a time shall be set off successively. If the blasts do not tally with the number fired, the misfired holes shall be carefully located after half an hour and when located, shall be exploded by drilling a fresh hole along the misfired hole (but not nearer than 600 mm from it) and by exploding a new charge.

A wooden tamping rod with a flat end shall be used to push cartridges home and metal rod or hammer shall not be permitted. The charges shall be placed firmly into place and not rammed or pounded. After a hole is filled to the required depth, the balance of the hole shall be filled with stemming which may consist of sand or stone dust or similar inert material.

Contractor shall preferably detonate the explosives electrically.

The explosives shall be exploded by means of a primer which shall be fired by detonating a fuse instantaneous detonator (F.I.D) or other approved cables. The detonators with F.I.D shall be connected by special nippers.

In dry weather and normal dry excavation, ordinary low explosive gunpowder may be used. In damp rock, high explosive like gelatine with detonator and fuse wire may be used. Under water or for excavation in rock with substantial accumulated seepage electric detonation shall be used.

Holes for charging explosive shall be drilled with pneumatic drills, the drilling pattern being so planned that rock pieces after blasting will be suitable for handling without secondary blasting.

When excavation has almost reached the desired level, hand trimming shall have to be done for dressing the surface to the desired level. Any rock excavation beyond an over break limit of 75 mm shall be filled up as instructed by Engineer, with concrete of strength not less than M100. The cost of filling such excess depth shall be borne by Contractor and the excavation carried out beyond the limit specified above will not be paid for. Stopping in rock excavation shall be done by hand trimming.

Contractor shall be responsible for any accident to workmen, public or Employer's property due to blasting operations. Contractor shall also be responsible for strict observance of rules, laid by Inspector of Explosives, or any other Authority duly constituted under the State and /or Union Government.

5A.3.9. Fill, Backfilling and Site Grading

5A.3.9.1 General

All fill material shall be subject to the Engineer’s approval. If any material is rejected by Engineer, the Contractor shall remove the same forthwith from the site. Surplus fill material shall be deposited/disposed off as directed by Engineer after the fill work is completed.

No earthfill shall commence until surface water discharges and streams have been properly intercepted or otherwise dealt with to the approval of the Engineer.

The Contractor shall not commence the placement of any fill or backfill at any location without the approval of the Engineer.

5A.3.9.2 Material

To the extent available, selected surplus soils from excavations shall be used as backfill. Backfill material shall be free from lumps, organic or other foreign material. All lumps of earth shall be broken or removed. Where excavated material is mostly rock, the boulders shall be broken into pieces not larger than 150 mm size, mixed with properly graded fine material consisting of murum or earth to fill the voids and the mixture used for filling.

If fill material is required to be imported, the Contractor shall make arrangements to bring such material from outside borrow pits. The material and source shall be subject to the prior approval of the Engineer. The approved borrow pit areas shall be cleared of all bushes, roots of trees, plants, rubbish, etc. Top soil containing foreign material shall be removed. The materials so removed shall be disposed off as directed by Engineer. The Contractor shall provide the necessary access roads to borrow areas and maintain the same if such roads do not exist, at his cost.

5A.3.9.3 Filling in pits and trenches around foundations of structures, walls, etc.

As soon as the work in foundations has been accepted and measured, the spaces around the foundations, structures, pits, trenches, etc., shall be cleared of all debris and filled with earth in layers not exceeding 15 cm, each layer being watered, rammed and properly consolidated, before the succeeding one is laid. Each layer shall be consolidated to the satisfaction of Engineer. Earth shall be rammed with approved mechanical compaction machines. Usually no manual compaction shall be allowed unless the Engineer is satisfied that in some cases manual compaction by tampers cannot be avoided. The final backfill surface shall be trimmed and leveled to a proper profile to the approval of the Engineer.

5A.3.9.4 Plinth Filling

Plinth filling shall be carried out with approved material as described hereinbefore in layers not exceeding 15cm, watered and compacted with mechanical compaction machines. The Engineer may, however, permit manual compaction by hand tampers where he is satisfied that mechanical compaction is not possible. When filling reaches the finished level, the surface shall be flooded with water, unless otherwise directed, for at least 24 hours, allowed to dry and then the surface again compacted as specified above to avoid settlement at a later stage. The finished level of the filling shall be trimmed to the level/slope specified.

Compaction of the plinth fill shall be carried out by means of 12 ton rollers smooth wheeled, sheep-foot or wobbly wheeled rollers. In case of compaction of granular material such as sands and gravel, vibratory rollers shall be used. A smaller weight roller may be used only if permitted by the Engineer. As rolling proceeds, water sprinkling shall be done to assist consolidation. Water shall not be sprinkled in case of sandy fills.

The thickness of each unconsolidated fill layer can in this case be upto a maximum of 300mm. The Contractor will determine the thickness of the layers in which fill has to be consolidated depending on the fill material and equipment used and the approval of the Engineer obtained prior to commencing filling.

Rolling shall commence from the outer edge and progress towards the centre and continue until compaction is to the satisfaction of Engineer, but in no case less than 10 passes of the roller will be accepted for each layer.

The compacted surface shall be properly shaped, trimmed and consolidated to an even and uniform gradient. All soft spots shall be excavated, then filled and consolidated.

At some locations/areas, it may not be possible to use rollers because of space restrictions, etc. The Contractor shall then be permitted to use pneumatic tampers, rammers, etc. and he shall ensure proper compaction.

5A.3.9.5 Sand Filling in Plinth and Other Places

Where backfilling is required to be carried out with local sand it shall be clean, medium grained and free from impurities. The filled-in-sand shall be kept flooded with water for 24 hours to ensure maximum consolidation. Any temporary work required to contain sand under flooded condition shall be on Contractor’s account. The surface of the consolidated sand shall be dressed to required level or slope. Construction of floors or other structures on sand fill shall not be started until the Engineer has inspected and approved the fill.

5A.3.9.6 Filling in Trenches

Filling in trenches for pipes and drains shall be commenced as soon as the joints of pipes and drains have been tested and passed. The backfilling material shall be properly consolidated by watering and ramming, taking due care that no damage is caused to the pipes.

Where the trenches are excavated in soil, the filling from the bottom of the trench to the level of the centre line of the pipe shall be done by hand compaction with selected approved earth in layers not exceeding 8 cm; backfilling above the level of the centre line of the pipes shall be done with selected earth by hand compaction, or other approved means in layers not exceeding 15 cm.

In case of excavation of trenches in rock, the filling upto a level 30 cm above the top of the pipe shall be done with fine materials such as earth, murum, etc. The filling up to the level of the centre line of the pipe shall be done by hand compaction in layers not exceeding 8 cm whereas the filling above the centre line of the pipe shall be done by hand compaction or approved means in layers not exceeding 15 cm. The filling from a level 30 cm above the top of the pipe to the top of the trench shall be done by hand or other approved mechanical methods with broken rock filling of size not exceeding 15 cm mixed with fine material as available to fill up the voids.

Filling of the trenches shall be carried out simultaneously on both sides of the pipe to avoid unequal pressure on the pipe.

In the case of water transmission, pipe lines works etc. for water transfer, the Contractor shall take proper precautions against the risks of floatation. Should any section of the pipeline be affected by floatation in the course of works the entire work shall be removed and then reinstalled to the satisfaction of Engineer.

5A.3.10. General Site Grading

Site grading shall be carried out as indicated in the drawings and as approved by the Engineer. Excavation shall be carried out as specified in the Specifications. Filling and compaction shall be carried out as specified under Clause 3.9 and elsewhere unless otherwise indicated below.

The fill has to be compacted in layers not exceeding 225 mm and leveled uniformly and compacted as indicated in Clause 3.9 before the next layer is deposited.

To ensure that the fill has been compacted as specified, field and laboratory tests shall be carried out by the Contractor at his cost. Field compaction tests shall be carried out in each layer of filling until the fill to the entire height has been completed. This shall hold good for embankments as well. The fill will be considered as incomplete if the desired compaction has not been obtained.

The Contractor shall protect the earth fill from being washed away by rain or damaged in any other way. Should any slip occur, the Contractor shall remove the affected material and make good the slip at his cost.

If so specified, the rock as obtained from excavation may be used for filling and leveling to indicated grades without further breaking. In such an event, filling shall be done in layers not exceeding 50 cms approximately. After rock filling to the approximate level, indicated above has been carried out, the void in the rocks shall be filled with finer materials such as earth, broken stone, etc. and the area flooded so that the finer materials fill up the voids. Care shall be taken to ensure that the finer fill material does not get washed out. Over the layer so filled, a 100 mm thick mixed layer of broken material and earth shall be laid and consolidation carried out by a 12 ton roller. No less than twelve passes of the roller shall be accepted before subsequent similar operations are taken up.

5A.3.11. Fill Density

The compaction, where so called for, shall comply with minimum 95% Modified Proctor density at moisture content differing not more than 4% from the optimum moisture content. The Contractor shall demonstrate adequately by field and laboratory tests that the specified density has been obtained.

5A.3.12. Lead

Lead for deposition/disposal of excavated material, shall be as specified in the respective item of work. No extra compensation is admissible on the grounds that the lead including that for borrowed material had to be transported over marshy or 'katcha' land/route.

5A.3.13. Measurements

All excavation shall be measured nett. Dimensions for purpose of payment shall be reckoned on the horizontal area of the excavation at the base for foundations of the walls, columns, footings, tanks, rafts or other foundations/structures to be built, multiplied by the mean depth from the surface of the ground in accordance with the drawings. Excavations in side slopes will not be paid for. Contractor may make such allowance in his rates to provide for excavation in side slopes keeping in mind the nature of the soil and safety or excavation. Reasonable working space, beyond concrete dimensions and shuttering where considered necessary in the opinion of Engineer will be allowed in excavation and considered for payment. However, if concreting is proposed against the excavated sides, no such over-excavation will be permitted. In such cases over-excavation shall be made good by Contractor with concrete of the same class as in the foundations at his cost.

In the case of water transmission, pipe lines works etc for water transfer trench excavation shall be measured using the dimensions detailed in the standard section shown on the Drawings. No payment will be made for working space except where clearly mentioned on the drawings. Excavation beyond the widths or depths required will not be paid for any additional concrete or bedding material required as a result of over-excavation at the Contractor's expense.

Backfilling as per specification the sides of foundations of columns, footings, structures, walls, tanks, rafts, trenches etc. with excavated material will not be paid for separately. It shall be clearly understood that the rate quoted for excavation including backfilling shall include stacking of excavated material as directed, excavation/packing of selected stacked material, conveying it to the place of final backfill, compaction etc. as specified. As a rule material to be backfilled shall be stacked temporarily within the basic lead of 100 metres unless otherwise directed by the Engineer. If Engineer directs/permits a lead of over 100 metres for such material, the conveyance of the material for the extra distance over the basic lead of 100 metres for backfilling will be paid for.

Payment for fill inside trenches, plinth or similar filling with selected excavated material will be made for only compaction as specified/directed. Cost of all other operations shall be deemed to have been covered in the rate quoted for excavation. Payment for this work will be made based on measurement of plinth/trench dimensions as per drawings. The plinth ground levels shall be surveyed before hand for this purpose. If no compaction is specified/desired such filling will not be separately paid for. In such an event the fill shall be leveled/finished to the profile as directed at no extra cost.

Backfilling, plinth filling etc. with borrowed earth will be paid for at rates quoted. The quoted rate shall include all operations such as clearing, excavation, lead and transport, fill, compaction etc, as specified. Actual quantity of consolidated filling or actual quantity or excavation in the borrow pits (less such top soil which has been excavated and not used for filling) whichever is less shall be measured and paid for in cubic metres. The lead, lift etc. shall be as indicated in the schedule of quantities.

Actual quantity of consolidated sand filling shall be measured and paid in cubic metres.

Volume of rock excavated shall be calculated on the basis of length, breadth and depth of excavation indicated on the drawings. No payment will be made for excavations/overbreak beyond payment line specified. Where such measurement is not possible as in the case of strata intermixed with soil, excavated rock shall be properly stacked as directed by Engineer and the volume of rock calculated on the basis of stack measurements after making appropriate allowance for voids. The allowance to be made for voids shall be decided by Engineer and this will not be a subject matter of dispute or appeal.

5A.3.14. Timber Shoring

Close timbering shall be done by completely covering the sides of the trenches and pits generally with short, upright members called 'polling boards'. These shall be of minimum 25 cm x 4 cm sections or as approved by the Engineer. The boards shall generally be placed in position vertically side by side without any gap on each side of the excavation and shall be secured by horizontal walings of strong wood at maximum 1.2 metre spacings, strutted with ballies or as approved by the Engineer. The length of the ballie struts shall depend on the width of the trench or pit. If the soil is very soft and loose, the boards shall be placed horizontally against each side of the excavation and supported by vertical walings, which in turn shall be suitably strutted. The lowest boards supporting the sides shall be taken into the ground and no portion of the vertical side of the trench or pit shall remain exposed, so as to render the earth liable to slip out.

Timber shoring shall be 'close' or 'open' type, depending on the nature of soil and the depth of pit or trench. The type of timbering shall be as approved by the Engineer. It shall be the responsibility of the Contractor to take all necessary steps to prevent the sides of excavations, trenches, pits, etc. from collapsing.

Timber shoring may also be required to keep the sides of excavations vertical to ensure safety of adjoining structures or to limit the slope of excavations, or due to space restrictions or for other reasons. Such shoring shall be carried out, except in an emergency, only under instructions from the Engineer.

The withdrawal of the timber shall be done carefully to prevent the collapse of the pit or trench. It shall be started at one end and proceeded with, systematically to the other end. Concrete or masonry shall not be damaged during the removal of the timber.

In the case of open timbering, the entire surface of the side of trench or pit is not required to be covered. The vertical boards of minimum 25 cm x 4 cm sections shall be spaced sufficiently apart to leave unsupported strips of maximum 50 cm average width. The detailed arrangement, sizes of the timber and the spacings shall be subject to the approval of the Engineer. In all other respects, the Specifications for close timbering shall apply to open timbering.

In case of large pits and open excavations, where shoring is required for securing safety of adjoining structures or for any other reasons and where the planking across sides of excavations/pits cannot be strutted against, suitable inclined struts supported on the excavated bed shall be provided. The load from such struts shall be suitably distributed on the bed to ensure no yielding of the strut. If however,

Engineer directs any timbering to be left-in, keeping in mind the type of construction or any other factor, Contractor shall be paid for at the scheduled item rate for such left-in timbering.

5A.3.15. Measurement

Unless separately provided for in the Schedule of Quantities, the actual effective area of shored faces as approved by Engineer shall be measured in sq.m. The area of planking embedded in the bed/sides of excavation will not be considered, nor the area supporting inclined struts in case of large pits/open excavation. All planks, boards, walings, verticals, struts, props and all other materials required for shoring and subsequent safe dismantling and removal shall be included in the quoted unit rates.

5A.3.16. Dewatering

The Contractor shall ensure that the excavation and the structures are free from water during construction and shall take all necessary precautions and measures to exclude ground/rain water so as to enable the works to be carried out in reasonably dry conditions in accordance with the construction programme. Sumps made for dewatering must be kept clear of the excavations/trenches required for further work. The method of pumping shall be approved by Engineer, but in any case, the pumping arrangement shall be such that there shall be no movement of subsoil or blowing in due to differential head of water during pumping. Pumping arrangements shall be adequate to ensure no delays in construction. The dewatering shall be continued for at least (7) seven days after the last pour of the concrete. The Contractor shall, however, ensure that no damage to the structure results on stopping of dewatering.

The Contractor shall study the sub-soil conditions carefully and shall conduct any tests necessary at the site with the approval of the Engineer to test the permeability and drainage conditions of the sub-soil for excavation, concreting etc., below ground level.

The scheme for dewatering and disposal of water shall be approved by the Engineer. The Contractor shall suitably divert the water obtained from dewatering from such areas of site where a build up of water in the opinion of the Engineer obstructs the progress of the work, leads to insanitary conditions by stagnation, retards the speed of construction and is detrimental to the safety of men, materials, structures and equipment.

When there is a continuous inflow of water and the quantum of water to be handled is considered in the opinion of Engineer, to be large, a well point system- single stage or multistage, shall be adopted. The Contractor shall submit to the Engineer, details of his well point system including the stages, the spacing, number and diameter of well points, headers etc., and the number, capacity and location of pumps for approval. Unless separately provided for in the Schedule of prices, the cost of dewatering shall be included in the item rate for excavation.

5A.3.17. Measurement

Unless separately provided for in the Schedule of quantities, dewatering is deemed to have been included in the unit rates quoted for excavation. If separately provided for, the unit of measurement shall be as indicated in the Schedule of Quantities.

5A.3.18. Rain Water Drainage

Grading in the vicinity of excavation shall be such as to exclude rain/ surface water draining into excavated areas. Excavation shall be kept clean of rain and such water as the Contractor may be using for his work by suitably pumping out the same. The scheme for pumping and discharge of such water shall be approved by the Engineer.

5A.3.19. Earthen Embankment Construction

5A.3.19.1 Scope

These Specifications shall apply to the construction of embankments including sub grades, earthen shoulders and miscellaneous backfills with approved materials obtained from roadway and drain excavation, borrow pits or other sources. All embankments, subgrade, earthen shoulders and miscellaneous backfills shall be constructed in accordance with the requirements of these Specifications and in conformity with the lines, grades, and cross-sections shown on the Drawings or as directed by the Engineer.

5A.3.19.2 Physical Requirements of materials

The materials used in embankments, sub grades, earthen shoulders and miscellaneous backfills shall be soil, moorum, gravel, a mixture of those or any other material approved by the Engineer. Such materials shall be free of logs, stumps, roots, rubbish or any other ingredient likely to deteriorate or affect the stability of the embankment/subgrade.

The following types of material shall be considered unsuitable for embankment:

Materials from swamps, marshes and bogs;

Peat, log, stump and perishable material; any soil that classifies as OL, OI, OH or Pt in accordance with IS: 1498.

Materials susceptible to spontaneous combustion;

Materials in a frozen conditions;

Clay having liquid limit exceeding 70 and plasticity index exceeding 45; and

Materials with salts resulting in leaching in the embankment.

Expansive clay exhibiting marked swell and shrinkage properties ("free swelling index" exceeding 50 percent when tested as per IS: 2720 Part 40) shall not be used as a fill material. Where expansive clay with acceptable "free swelling index" value is used as a fill material, subgrade and top 500 mm portion of the embankment just below subgrade shall be non-expansive in nature.

Any fill material with a soluble sulphate content exceeding 1.9 grams of sulphate (expressed as SO3) per litre when tested in accordance with BS: 1377 Test 10, but using a 2:1 water-soil ratio shall not be deposited within 500 mm or other distance described in the Contract, of concrete, cement bound materials or other cementitious materials forming part of the Permanent Works.

Materials with a total sulphate content (expressed as SO3) exceeding 0.5 percent by mass, when tested in accordance with BS: 1377 Test 9 shall not be deposited within 500 mm, or other distances described in the Contract, of metallic items forming part of the Permanent Works.

The size of the coarse material in the mixture of earth shall ordinarily not exceed 75 mm when being placed in the embankment and 50 mm when placed in the subgrade. However, the Engineer may at his discretion permit the use of material coarser than this also if he is satisfied that the same will not present any difficulty as regards the placement of fill material and its compaction to the requirements of these Specifications. The maximum particle size shall not be more than two-thirds of the compacted layer thickness.

Ordinarily, only the materials satisfying the density requirements given in Table 5-3 shall be employed for the construction of the embankment and the subgrade.

Table-1. Density Requirements of Embankment and Subgrade Materials

Sr.	Type of Work	Maximum laboratory dry unit weight when tested as per IS: 2270 (Part 8)
1.	Embankments up to 3 metres height, not subjected to extensive flooding.	Not less than 15.2 kN/cum.
2.	Embankments exceeding 3 metres height or embankments of any height subject to long periods of inundation	Not less than 16.0 kN/cum.
3.	Sub grades and earthen shoulders / verges / backfill	Not less than 17.5 kN/cum.

Notes:

This Table is not applicable for lightweight fill material e.g. cinder, fly ash etc.

The Engineer may relax these requirements at his discretion taking into account the availability of materials for construction and other relevant factors.

The material to be used in subgrade should also satisfy design CBR at the dry unit weight applicable as per Table-II .

5A.3.19.3 General requirements of materials

The materials for embankment shall be obtained from approved sources with preference given to materials becoming available from nearby roadway excavation or any other excavation under the same Contract.

The work shall be so planned and executed that the best available materials are saved for the subgrade and the embankment portion just below the subgrade.

5A.3.19.4 Borrow Materials

Where the materials are to be obtained from designated borrow areas, the location, size and shape of these areas shall be as indicated by the Engineer and the same shall not be opened without his written permission. Where specific borrow areas are not designated by the Employer / the Engineer, arrangement for locating the source of supply of material for embankment and subgrade as well as compliance to environmental requirements in respect of excavation and borrow areas as stipulated, from time to time by the Ministry of Environment and Forests, Government of India and the local bodies, as applicable, shall be the sole responsibility of the Contractor.

Borrow pits along the road shall be discouraged. If permitted by the Engineer, these shall not be dug continuously. Ridges of not less than 8 m width should be left at intervals not exceeding 300 m. Small drains shall be cut through the ridges to facilitate drainage. The depth of the pits shall be so regulated that their bottom does not cut an imaginary line having a slope of 1 vertical to 4 horizontal projected from the edge of the final section of the bank, the maximum depth in any case being limited to 1.5 m. Also, no pit shall be dug within the offset width from the toe of the embankment required as per the consideration of stability with a minimum width of 10 m.

Haulage of material to embankments or other areas of fill shall proceed only when sufficient spreading and compaction plants is operating at the place of deposition.

No excavated acceptable material other than surplus to requirements of the Contract shall be removed from the site. Should the Contractor be permitted to remove acceptable material from the site to suit his operational procedure, then he shall make good any consequent deficit of material arising there from.

Where the excavation reveals a combination of acceptable and unacceptable materials, the Contractor shall, unless otherwise agreed by the Engineer, carry out the excavation in such a manner that the acceptable materials are excavated separately for use in the permanent works without contamination by the unacceptable materials. The acceptable materials shall be stockpiled separately.

The Contractor shall ensure that he does not adversely affect the stability of excavation or fills by the methods of stockpiling materials, use of plants or siting of temporary buildings or structures.

The Contractor shall obtain representative samples from each of the identified borrow areas and have these tested at the site laboratory following a testing programme approved by the Engineer. It shall be ensured that the subgrade material when compacted to the density requirements as in Table II shall yield the design CBR value of the subgrade.

Table-II . Compaction Requirements for Embankment and Subgrade

Sr	Type of work/ material	Relative compaction as percentage of max. laboratory dry density as per IS: 2720 (Part 8)
1.	Subgrade and earthen shoulders	Not less than 97
2.	Embankment	Not less than 95
3.	Expansive Clays	
	a) Subgrade and 500 mm portion just below the subgrade	Not allowed
	b) Remaining portion of embankment	Not less than 90

The Contractor shall at least 7 working days before commencement of compaction submit the following to the Engineer for approval:

The values of maximum dry density and optimum moisture content obtained in accordance with IS: 2720 (Part 7) or (Part 8), as the case may be, appropriate for each of the fill materials he intends to use.

A graph of density plotted against moisture content from which each of the values in (1) above of maximum dry density and optimum moisture content were determined.

The Dry density-moisture content-CBR relationships for light, intermediate and heavy compactive efforts (light corresponding to IS: 2720 (Part 7), heavy corresponding to IS: 2720 (Part 8) and intermediate in-between the two) for each of the fill materials he intends to use in the subgrade.

Once the above information has been approved by the Engineer, it shall from the basis for compaction.

5A.3.19.5 Construction Operations for Embankments

Setting out

After the site has been cleared to Section-1, the work shall be set out. The limits of embankment/subgrade shall be marked by fixing batter pegs on both sides at regular intervals as guides before commencing the earthwork. The embankment / subgrade shall be built sufficiently wider than the design dimension so that surplus materials may be trimmed, ensuring that the remaining material is to the desired density and in position specified and conforms to the specified side slopes.

Dewatering

If the foundation of the embankment is in an area with stagnant water, and in the opinion of the Engineer it is feasible to remove it, the same shall be removed by bailing out or pumping, as directed by the Engineer and the area of the embankment foundation shall be kept dry. Care shall be taken to discharge the drained water so as not to cause damage to the works, crops or any other property. Due to any negligence on the part of the Contractor, if any such damage is caused, it shall be the sole responsibility of the Contractor to repair / restore it to original condition or compensate the damage at his own cost. If the embankment is to be constructed under Water, Clause 3.19.5 shall apply.

Stripping and storing topsoil

In localities where most of the available embankment materials are not conducive to plant growth, or when so directed by the Engineer, the topsoil from all areas of cutting and from all areas to be covered by embankment foundation shall be stripped to specified depths not exceeding 150 mm and stored in stockpiles of height not exceeding 2 m for covering embankment slopes, cut slopes and other disturbed areas where re-vegetation is desired. Topsoil shall not be unnecessarily trafficked either before stripping or when in a stockpile. Stockpiles shall not be surcharged or otherwise loaded and multiple handling shall be kept to a minimum.

Compacting ground supporting Embankment / Subgrade

When necessary, the original ground shall be leveled to facilitate placement of first layer of embankment, scarified, mixed with water and then compacted by rolling so as to achieve minimum dry density as given in Table-II.

In case where the difference between the subgrade level (top of the subgrade on which pavement rests) and ground level is less than 0.5 m and the ground does not have 97 percent relative compaction with respect to the dry density as given in Table 5-4, the ground shall be loosened up to a level 0.5 m below the subgrade level, watered and compacted in layers in accordance with Clause 3.19.4 to not less than 97 percent of dry density as given in Table-II.

Where so directed by the Engineer, any unsuitable material occurring in the embankment foundation shall be removed and replaced by approved materials laid in layers to the required degree of compaction.

Embankment or subgrade work shall not proceed until the foundations of embankments/subgrade have been inspected by the Engineer for satisfactory condition and approved.

Any foundation treatment specified for embankments especially high embankments, resting on suspect foundations as revealed buy borehole logs shall be carried our in a manner and to the depth as desired by the Engineer. Where the ground on which and embankment is to be built has any of the material types specified in Clause 3.19.2, at least 500 mm of such material must be removed and replaced by acceptable fill material before embankment construction commences.

Spreading material in layers and bringing to appropriate moisture content

The embankment and subgrade material shall be spread in layers of uniform thickness not exceeding 200 mm compacted thickness over the entire width of embankment by mechanical means, finished by a motor grader and compacted as per Clause 3.19.4. The motor grader blade shall have hydraulic control suitable for initial adjustment and maintain the same so as to achieve the specific slope and grade. Successive layers shall not be placed until the layer under construction has been thoroughly compacted to the specified requirements as in Table-II and got approved by the Engineer. Each compacted layer shall be finished parallel to the final cross-section of the embankment.

Moisture content of the material shall be checked at the site of placement prior to commencement of compaction; if found to be out of agreed limits, the same shall be made good. Where water is required to be added in such construction, water shall be sprinkled from a water tanker fitted with sprinkler capable of applying water uniformly with a controllable rate of flow to variable widths of surfaces but without any flooding. The water shall be added uniformly and thoroughly mixed in soil by blading, discing or harrowing until and uniform moisture content is obtained throughout the depth of the layer.

If the; material delivered to the roadbed is too wet, it shall be dried, by aeration and exposure to the sun, till the; moisture content is acceptable for compaction. Should circumstances arise, where owing to wet weather, the moisture content cannot be reduced to the required amount by the above procedure, compaction work shall be suspended.

Moisture content of each layer of soil shall be checked in accordance with IS: 2720 (Part 2), and unless otherwise mentioned, shall be so adjusted, making due allowance for evaporation losses, that at the time of compaction it is in the range of 1% above to 2% below the optimum moisture content determined in accordance with IS: 2720 (Part 7) or IS: 2720 (Part 8) as the case may be. Expansive clays shall, however, be compacted at moisture content corresponding to the specified dry density, but on the wet side of the optimum moisture content obtained from the laboratory compaction curve.

After adding the required amount of water, the soil shall be processed by means of graders, harrows, rotary mixers or as otherwise approved by the Engineer unit the layer is uniformly wet.

Clods or hard lumps of earth shall be broken to have a maximum size of 75 mm when being placed in the embankment and a maximum size of 50 mm when being placed in the subgrade.

Embankment and other areas of fill shall, unless otherwise required in the Contract or permitted by the Engineer, be constructed evenly over their full width and their fullest possible extent and the Contractor shall control and direct construction plant and other vehicular traffic uniformly over them. Damage by construction plant and other vehicular traffic shall be made good by the Contractor with material having the same characteristics and strength as the material had before it was damaged.

Embankments and other areas of unsupported fills shall not be constructed with steeper side slopes, or to greater widths than those shown in the Contract, except to permit adequate compaction at the edges before trimming back, or to obtain the final profile following any settlement of the fill and the underlying material.

Whenever fill is to be deposited against the face of a natural slope, or sloping earthworks face including embankments, cuttings, other fills and excavations steeper than 1 vertical on 4 horizontal, such faces shall be benched as per Clause 3.19.5 immediately before placing the subsequent fill.

All permanent faces of side slopes of embankments and other areas of fill formed shall, subsequent to any trimming operations, be reworked and sealed to the satisfaction of the Engineer by tracking a tracked vehicle, considered suitable by the Engineer, on the slope or any other method approved by the Engineer.

Compaction

Only the compaction equipment approved by the Engineer shall be employed to compact the different material types encountered during construction. Smooth wheeled, vibratory, pneumatic tyred, sheep foot or pad foot rollers, etc., of suitable size and capacity as approved by the Engineer shall be used for the different types and grades of materials required to be compacted either individually or in suitable combinations.

The compaction shall be done with the help of vibratory roller of 80 to 100 kN static weight with plain or pad foot drum or heavy pneumatic tyred roller of adequate capacity capable of achieving required compaction.

The Contractor shall demonstrate the efficiency of the equipment he intends to use by carrying out compaction trials. The procedure to be adopted for these site trials shall first be submitted to the Engineer for approval.

Earthmoving plant shall not be accepted as compaction equipment nor shall the use of a lighter category of plant to provide any preliminary compaction to assist the use of heavier plant be taken into account.

Each layer of the material shall be thoroughly compacted to the densities specified in Table 5-4. Subsequent layers shall be placed only after the finished layer has been tested according to Clause 903.2.2 of MoST Specifications for Roads and Bridge Works (IV Revision) and accepted by the Engineer. The Engineer may permit measurement of field dry density by a nuclear moisture / density gauge used in accordance with agreed procedure and the gauge is calibrated to provide results identified to that obtained from tests in accordance with IS: 2720 (Part 28). A record of the same shall be maintained by the Contractor.

When density measurement reveal any soft areas in the embankment / subgrade / earthen shoulders, further compaction shall be carried out as directed by the Engineer. If inspite of that the specified compaction is not achieved, the material in the soft areas shall be removed and replaced by approved material, compacted to the density requirements and satisfaction of the Engineer.

Drainage

The surface of the embankment / subgrade at all times during construction shall be maintained at such a cross fall (not flatter than that required for effective drainage of an earthen surface) as will shed water and prevent ponding.

Repairing of damages caused by rain / spillage of water

The soil in the affected portion shall be removed in such areas as directed by the Engineer before next layer is laid and refilled in layers and compacted using appropriate mechanical means such as small vibratory roller, plate compactor or power rammer to achieve the required density in accordance with Clause 3.19.5. If the cut is not sufficiently wide for use of required mechanical means for compaction, the same shall be widened suitably to permit their use for proper compaction. Tests shall be carried out as directed by the Engineer to ascertain the density requirements of the repaired area. The work of repairing the damages including widening of the cut, if any, shall be carried out by the Contractor at his own cost, including the arranging of machinery / equipment for the purpose.

Finishing operations

Finishing operations shall include the work of shaping and dressing the shoulders / verge / roadbed and side slopes to conform to the alignment, levels, cross-sections and dimensions shown on the Drawings or a directed by the Engineer subject to the surface tolerance described in **Clause 902** of MoST Specifications for Roads and Bridge Works (IV Revision). Both the upper and lower ends of the side slopes shall be rounded off to improve appearance and to merge the embankment with the adjacent terrain.

The topsoil, removed and conserved earlier shall be spread over the fill slopes as per directions of the Engineer to facilitate the growth of vegetation. Slopes shall be roughened and moistened slightly prior to the application of the topsoil in order to provide satisfactory bond. The depth of the topsoil shall be sufficient to sustain plant growth, the usual thickness being from 75 mm to 150 mm.

Where directed, the slopes shall be turfed with sods in accordance with **Clause 3.20**. If seeding and mulching of slopes is prescribed, this shall be done to the requirement of **Clause 3.21**.

When earthwork operations have been substantially completed, the road area shall be cleared of all debris, and ugly scars in the construction area responsible for objectionable appearance eliminated.

5A.3.19.6 Construction of Embankment and Subgrade under Special Conditions

Earthwork for widening existing road embankment

When an existing embankment and / or subgrade is to be widened and its slope are steeper than 1 vertical on 4 horizontal, continuous horizontal benches, each at least 300 mm wide, shall be cut into the old slope for ensuring adequate bond with the fresh embankment / subgrade material to be added. The material obtained from cutting of benches could be utilized in the widening of the embankment / subgrade. However, when the existing slope against which the fresh material is to be placed is flatter than 1 vertical on 4 horizontal, the slope surface may only be ploughed or scarified instead of resorting to benching.

Where the width of the widened portions is insufficient to permit the use of conventional rollers, compaction shall be carried out with the help of small vibratory rollers / plate compactors / power rammers of any other appropriate equipment approved by the Engineer. End dumping of material from trucks for widening operations shall be avoided except in difficult circumstances when the extra width is too narrow to permit the movement of any other types of hauling equipment.

Earthwork for embankment and subgrade to be placed against sloping ground:

Where an embankment / subgrade is to be placed against sloping ground, the latter shall be appropriately benched or ploughed / scarified as required in **Clause 3.19.5** before placing the embankment / subgrade material. Extra earthwork involved in benching or due to ploughing / scarifying etc. shall be considered incidental to the work.

For wet conditions, benches with slightly inward fall subsoil drains at the lowest point shall be provided as per the Drawings, before the fill is placed against sloping ground.

Earthwork over existing road surface:

Where the embankment is to be placed over an existing road surface, the work shall be carried out as indicated below:

If the existing road surface is of granular or bituminous type and lies within 1 m of the new subgrade level, the same shall be scarified to a depth of 50 mm or more if specified, so as to provide ample bond between the old and new material ensuring that at least 500 mm portion below the top of new subgrade level is compacted to the desired density.

If the existing road surface is of cement concrete type and lies within 1 m of the new subgrade level the same shall be removed completely.

If the level difference between the existing road surface and the new formation level is more than 1 m, the existing surface shall be permitted to stay in place without any modification.

Embankment and subgrade around structures:

To avoid interference with the construction of abutments, wing walls or return walls of culvert / bridge structures, the Contractor shall, at points to be determined by the Engineer suspend work on embankment forming approaches to such structures, until such time as the construction of the latter is sufficiently advanced to permit the completion of approaches without the risk of damage to the structure.

Unless directed otherwise, the filling around culverts, bridges and other structures up to a distance of twice the height of the road from the back of the abutment shall be carried out independent of the work on the main embankment. The fill material shall not be placed against any abutment or wing wall, unless permission has been given by the Engineer but in any case not until the concrete or masonry has been in position for 14 days. The embankment and subgrade shall be brought up simultaneously in equal layers on each side of the structure to avoid displacement in equal layers on each side of the structure to avoid displacement and unequal pressure. The sequence of work in this regard shall be got approved from the Engineer.

The material used for backfill shall not be an organic soil or highly plastic clay having plasticity index and liquid limit more than 20 and 40 respectively when tested according to IS: 2720 (Part 5). Filling behind abutments and wing walls for all structures shall conform to the general guidelines given in Appendix 6 of IRC:78 (Standard Specifications and Code of Practice for Road Bridges-Section VII) in respect of the type of material, the extent of backfill, its laying and compaction etc. The fill material shall be deposited in horizontal layers in loose thickness and compacted thoroughly to the requirements of **Table-II.**

Where the provision of any filter medium is specified behind the abutment, the same shall be laid in layers simultaneously with the laying of fill material. The material used for filter shall conform to the requirements for filter medium spelt out in **Clause 2502** of MoST Specifications for Roads and Bridge Works (IV Revision) unless otherwise specified in the Contract.

Where it may be impracticable to use conventional rollers, the compaction shall be carried out by appropriate mechanical means such as small vibratory roller, plate compactor or power rammer. Care shall be taken to see that the compaction equipment does not hit or come too close to any structural member so as to cause any damage to them or excessive pressure against the structure.

Construction of Embankment over Ground Incapable of Supporting Construction Equipment:

Where embankment is to be constructed across ground which will not support the weight of repeated heavy loads of construction equipment, the first layer of the fill may be constructed by placing successive loads of material in a uniformly distributed layer of a minimum thickness required to support the construction equipment as permitted by the Engineer. The Contractor, if so desired by him, may also use suitable geosynthetic material to increase the bearing capacity of the foundation. This exception to normal procedure will not be permitted where, in the opinion of the Engineer, the embankments could be constructed in the approved manner over such ground by the use of lighter or modified equipment after proper ditching and drainage have been provided. Where this exception is permitted, the selection of the material and the construction procedure to obtain an acceptable layer shall be the responsibility of the Contractor. The cost of providing suitable traffic conditions for construction equipment over any area of the Contract will be the responsibility of the Contractor and no extra payment will be made to him. The remainder of the embankment shall be constructed as specified in Clause 3.19.4.

Embankment construction under water

Where filling or backfilling is to be placed under water, only acceptable granular material or rock shall be used unless otherwise approved by the Engineer. Acceptable granular material shall consist of graded, hard durable particles with maximum particle size not exceeding 75 mm. The material should be non-plastic having uniformity coefficient of not less than 10. The material placed in open water shall be deposited by end tipping without compaction.

Earthwork for high embankment

In the case of high embankments, the Contractor shall normally use the material from the specified borrow area. In case he desires to use different material for his own convenience, he shall have to carry out necessary soil investigations and redesign the high embankment at his own cost. The Contractor shall then furnish the soil test data and design of high embankment for approval of the Engineer, who reserve the right to accept or reject it.

If necessary, stage construction of fills and any controlled rates of filling shall be carried out in accordance with the Contract including installation of instruments and its monitoring.

Where required, the Contractor shall surcharge embankments or other areas of till with approved material for the periods specified in the Contract. If settlement of surcharged fill results in any surcharging material, which is unacceptable for use in the fill being surcharged, lying below formation level, the Contractor shall remove the unacceptable material and dispose it as per direction of the Engineer. He shall then bring the resultant level up to formation level with acceptable material.

Settlement period

Where settlement period is specified in the Contract, the embankment shall remain in place for the required settlement period before excavating for abutment, wingwall, retaining wall, footings, etc., or driving foundation piles. The duration of the required settlement period at each location shall be as provided for in the Contract or as directed by the Engineer.

5A.3.19.7 Plying of Traffic

Construction and other vehicular traffic shall not use the prepared surface of the embankment and / or subgrade without the prior permission of the Engineer. Any damage arising out of such use shall, however, be made good by the Contractor at his own expense as directed by the Engineer.

5A.3.19.8 Surface Finish and Quality Control of Work

The surface finish of construction of subgrade shall conform to the requirements of Clause 902 of MoST Specifications for Roads and Bridge Works (IV Revision). Control on the quality of materials and works shall be exercised in accordance with Clause 903 of MoST Specifications for Roads and Bridge Works (IV Revision).

5A.3.19.9 Subgrade Strength

It shall be ensured prior to actual execution that the borrow area material to be used in the subgrade satisfies the requirements of design CBR.

Subgrade shall be compacted and finished to the design strength consistent with other physical requirements. The actual laboratory CBR values of constructed subgrade shall be determined on undisturbed samples cut out from the compacted subgrade in CBR mould fitted with cutting shoe or on remoulded samples, compacted to the field density at the field moisture content.

5A.3.20. Soil Erosion and Sedimentation Control

5A.3.20.1 Scope

This work shall consist of measures as shown on plans or as directed by the Engineer to control soil erosion, sedimentation and water pollution, through use of berms, dikes, sediment basins, fibre mats, mulches, grasses, slope drains, and other devices.

5A.3.20.2 Materials

All materials shall meet commercial grade standards and shall be approved by the Engineer before being used in the work.

5A.3.20.3 Construction Operations

Prior to the start of the relevant construction, the Contractor shall submit to the Engineer for approval his schedules for carrying out temporary and permanent erosion / sedimentation control works as are applicable for the items of clearing and grubbing, roadway and drainage excavation, embankment / subgrade construction, bridges and other structures across water course, pavement courses and shoulders. He shall also submit for approval his proposed method of erosion / sedimentation control on service road and borrow pits and his plan for disposal of waste materials. Work shall not be started until the erosion / sedimentation control schedules and methods of operations for the applicable construction have been approved by the Engineer.

The surface area of erodible earth material exposed by clearing and grubbing, excavation, borrow and fill operations shall be limited to the extent practicable. The Contractor may be directed to provide immediate permanent or temporary erosion and sedimentation control measures to prevent soil erosion and sedimentation that will adversely affect construction operations, damage adjacent properties, or cause contamination of nearby streams or other water courses, lakes, reservoirs etc. Such work may involve the construction of temporary berms, dikes, sediment basins, slope drains and use of temporary mulches, fabrics, mats, seeding, or other control devices or methods as necessary to control erosion and sedimentation. Cut and fill slopes shall be seeded and turfed as required on the plans.

The Contractor shall be required to incorporated all permanent erosion and sedimentation control features into the project at the earliest practicable time as outlined in his accepted schedule to minimize the need for temporary erosion and sedimentation control measures.

Temporary erosion / sedimentation and pollution control measures will be used to control the phenomenon of erosion, sedimentation and pollution that may develop during normal construction practices, but may neither be foreseen during design stage nor associated with permanent control features on the Project.

Where erosion or sedimentation is likely to be a problem, clearing and grubbing operations should be so scheduled and performed that grading operations and permanent erosion or sedimentation control features can follow immediately thereafter if the project conditions permit; otherwise temporary erosion or sedimentation control measure may be required between successive construction stages. Under no conditions shall a large surface area of erodible earth material be exposed at one time by clearing and grubbing or excavation without prior approval of the Engineer.

The Engineer may limit the area of excavation, borrow and embankment operations in progress, commensurate with the Contractor’s capability and progress in keeping the finish grading, mulching, seeding and other such permanent erosion, sedimentation and pollution control measures, in accordance with the accepted schedule. Should seasonal limitations make such coordination unrealistic, temporary erosion / sedimentation control measures shall be taken immediately to the extent feasible and justified.

In the event temporary erosion, sedimentation and pollution control measures become necessary due to the Contractor's negligence, carelessness or failure to install permanent controls as a part of the work as scheduled or ordered by the Engineer, these shall be carried out at the Contractor's own expense. Temporary erosion, sedimentation and pollution control work required, which is not attributed to the Contractor's negligence, carelessness of failure to install permanent controls, will be performed as ordered by the Engineer.

Temporary erosion, sedimentation and pollution control may include construction work outside the right-of-way where such work is necessary as result of road construction such as borrow pit operations, service roads and equipment storage sites.

The temporary erosion, sedimentation and pollution control features installed by the Contractor shall be acceptably maintained by him till these are needed, unless otherwise agreed by the Engineer.

5A.3.21. Turfing with Sods

5A.3.21.1 Scope

This work shall consist of furnishing and laying of the live sod of perennial turf forming grass on embankment slopes, verges (earthen shoulders) or other locations shown on the Drawings or as directed by the Engineer. Unless otherwise specified, the work shall be taken up as soon as possible following construction of the embankment, provided the season is favourable for establishment of the sod.

5A.3.21.2 Materials

The sod shall consist of dense, well-rooted growth of permanent and desirable grasses, indigenous to the locality where it is to be use, and shall be practically free from weeds or other undesirable matter. At the time the sod is cut, the grass on the sod shall have a length of approximately 50 mm and the sod shall have freed of debris.

Thickness of the sod shall be as uniform as possible, with some 50-80 mm or so of soil covering the grass roots depending on the nature of the sod, so that practically all the dense root system of the grasses is retained in the sod strip. The sods shall be cut in rectangular strips of uniform width, not less than about 250 mm X 300 mm in size but not so large that it is inconvenient to handle and transport these without damage. During wet weather, the sod shall be allowed to dry sufficiently to prevent rearing during handling and during dry weather shall be watered before lifting to ensure its vitality and prevent the dropping of the soil in handling.

5A.3.21.3 Construction Operations for Turfing with Sods

Preparation of earth bed

The area to be sodded shall have been previously constructed to the required slope and cross section. Soil on the area shall be loosened, freed of all stones larger than 50 mm size, sticks, stumps and any undesirable foreign matter, and brought to a reasonably fine granular texture to a depth of not less than 25 mm for receiving the sod.

Where required, topsoil shall be spread over the slopes. Prior to placing the topsoil, the slopes shall be scarified to a depth which, after settlement, will provide the required nominal depth shown on the plans. Spreading shall not be done when the ground is excessively wet.

Following soil preparation and top soiling, where required, fertilizer and ground limestone when specified shall be spread uniformly at the rate indicated on the plans. After spreading, the materials are incorporated in the soil by discing or other means to the depths shown on the plans.

Placing the sods

The prepared sod bed shall be moistened to the loosened depth, if not already sufficiently moist, and the sod shall be placed thereon within approximately 24 hours after the same had been cut. Each sod strip shall be laid edge to edge and such that the joints caused by abutting ends are staggered. Every strip, after it is snugly placed against the strips already in position, shall be lightly tamped with suitable wooden or metal tampers so as to eliminate air pockets and to press it into the underlying soil.

On side slopes steeper than 2 (horizontal) to 1 (vertical), the laying of sods shall be started from bottom upwards. At points where water may flow over a sodded area, the upper edges of the sod strips shall be turned into the soil below the adjacent area and a layer of earth placed over this followed by its through compaction.

Staking the sods

Where the side slope is 2 (horizontal) to 1 (vertical) or steeper and the distance along the slope is more than 2 m, the sods shall be staked with pegs or nails spaced approximately 500 to 1000 mm along the longitudinal axis of the sod strips. Stakes shall be driven approximately plumb through the sods to be almost flush with them.

Top dressing

After the sods have been laid in position, the surface shall be cleaned of loose sod, excess soil and other foreign material. Thereafter, a thin layer of topsoil shall be scattered over the surface of top dressing and the area thoroughly moistened by sprinkling with water.

Watering and maintenance

The sods shall be watered by the Contractor for a period of at least four weeks after laying. Watering shall be so done as to avoid erosion and prevent damage to sodded areas by wheels of water tanks.

The Contractor shall erect necessary warning signs and barriers, repair or replace sodded areas failing to show uniform growth of grass or damaged by his operations and shall otherwise maintain the sod at his cost until final acceptance.

5A.3.22. Seeding and Mulching

5A.3.22.1 Scope

This shall consist of preparing slopes, placing topsoil, furnishing all seeds, commercial or organic fertilizers and mulching materials, providing jute netting and placing and incorporation the same on embankment slopes or other locations designated by the Engineer or shown in the Contract documents.

5A.3.22.2 Materials

Seeds

The seeds shall be approved quality and type suitable for the soil on which these are to be applied, and shall have acceptable purity and germination to requirements set down by the Engineer.

Fertilizer

This shall consist of standard commercial materials and conform to the grade specified. Organic manure shall be fully purified organic matter such as cow dung.

Mulching materials

This shall consist of straw, hay wood shavings or sawdust and shall be delivered dry. They shall be reasonably free of weed seed and such foreign materials as may detract from their effectiveness as mulch or be injurious to the plant growth.

Topsoil

Topsoil shall not be obtained from an area known to have noxious weeds growing in it. If treated with herbicides or sterilents, it shall be got tested by appropriate agricultural authority to determine the residual in the soil. Topsoil shall be contain less than 2 per cent and more than 12 per cent organic matter.

Bituminous Emulsion

A suitable grade of bituminous cutback or emulsion used as a tie down for mulch shall be as described in the Contract document or as desired by the Engineer. Emulsified bitumen shall not contain any solvent or diluting agent toxic to plant life.

Netting

Jute netting shall be undyed jute yam woven into a uniform open weave with approximate 2.5 cm square openings. Geonetting shall be made of uniformly extruded rectangular mesh having mesh opening of 2 cm x 2 cm. The colour may be black or green. It shall weigh not less than 3.8 kg per 1000 sq. m.

5A.3.22.3 Seeding Operations

Seed-bed Preparation

The area to be seeded shall be brought to the required slope and cross-section by filling, reshaping eroded areas and refinishing slopes, median etc. Topsoil shall be evenly spread over the specified areas to the depth shown on the plans, unless otherwise approved by the Engineer. The see-bed preparation shall consist of eliminating all live plants by suitable means using agricultural implements. All stones 150 mm in smallest dimension and larger shall be removed. The soil shall be excavated on the contour to a depth of 100 mm. All clods large than 25 mm in diameter shall be crushed and packed. Where necessary, water shall then be applied. All topsoil shall be compacted unless otherwise specified or approved by the Engineer. Compaction shall be by slope compactor, cleated tractor or similar equipment approved by the Engineer. Equipment shall be so designed and constructed as to produce a uniform rough textured surface ready for seeding and mulching and which will bond the topsoil to the underlying material. The entire area shall be covered by a minimum of 4 passes or 2 round trips of the roller or approved equipment.

Fertilizer application

Fertilizer to the required quantities shall be spread and thoroughly incorporated into the soil surface as a part of the seed-bed preparation.

Planting of seeds

All seeds shall be planted uniformly at the approved rate. Immediately after sowing, the area shall be raked, dragged or otherwise treated so as to cover the seeds to a depth of 6 mm. The operation of seed sowing shall not be performed when the ground is muddy or when the soil or weather conditions would otherwise prevent proper soil preparation and subsequent operations.

Soil Moisture and Watering requirements

Soil moisture shall exist throughout the zone from 25 mm to at least 125 mm below the surface at the time of planting. Watering off the seeded areas shall be carried out as determined by the Engineer.

5A.3.22.4 Mulching, Applying Bituminous Emulsion and Jute Netting / Geonetting

Within 24 hours of seeding, mulching material mixed with organic manure shall be placed so as to form a continuous, unbroken cover of approximate uniform thickness of 25 mm using an acceptable mechanical blower. Mulching material shall be held in place and made resistant to being blown away by suitable means approved by the Engineer. When called for in the Contract documents, mulch material shall be anchored in place with bituminous emulsion applied at the rate of 2300 liters per hectare. Any mulch disturbed or displaced following application shall be removed, reseeded and remulched as specified. Jute netting / Geonetting shall be unrolled and placed parallel to the flow of water immediately following the bringing, to finished grade, the area specified on the plans or the placing of seed and fertilizer. Where more than one strip is required to cover the given areas, they shall overlap a minimum of 100 mm. Jute netting / Geonetting shall be held in place by approved wire staples, pins, spikes or wooden stakes driven vertically into the soil

5A.3.22.5 Maintenance

The Contractor shall maintain all seeded and mulched areas until final acceptance. Maintenance shall include protection of traffic by approved warning signs or barricades and repairing any areas damaged following the seeding and mulching operations. If mulched areas become damaged, the area shall be reshaped and then seeded and mulched again as originally specified.

5A.3.23. Preparation and Surface Treatment of Formation

Preparation and surface treatment of the formation, that is top of the subgrade, shall be carried out only after completion of any specified subgrade drainage and unless otherwise agreed by the Engineer, immediately prior to laying the sub-base or the road base where no sub-base is required. The sequence of operations shall be as follows:

All surfaces below carriageway, lay byes, footways and hard shoulders shall, after reinstatement of any soft areas to the required Specifications be well cleaned and freed of mud and slurry.

The surface shall be compacted by 4 passes of a smooth wheeled roller of 80 to 100 kN weight after spraying requisite amount of water, if required, before the commencement of rolling.

The formation shall, wherever necessary, be regulated and trimmed to the requirements of Clause 5.20.4.9 with motor grader.

The trimmed formation shall be rolled by one pass of smooth wheeled roller of 80 to 100 kN weight after spraying requisite amount of water, if required, before the commencement of rolling.

Where the completed formation is not immediately covered with sub base or road base material, its moisture content shall be maintained to prevent cracking in the formation by suitable measures as approved by the Engineer. The entire work of surface treatment of formation shall be deemed as incidental to the work of sub-base / base course to be provided on the subgrade and as such no extra payment shall be made for the same.

5A.3.24. Works to be Kept Free of Water

The Contractor shall arrange for the rapid dispersal of water collected / accumulated on the earthwork or completed formation during construction or on the existing roadway or which enters the earthwork or any other item of work from any source, and where practicable, the water shall be discharged into the permanent outfall of the drainage system. The arrangement shall be made in respect of all earthwork including excavation for pipe trenches, foundations or cuttings.

The Contractor shall provide, where necessary, temporary water courses, ditches, drains, pumping or other means for maintaining the earthwork free from water. Such provisions shall include carrying out the work of forming the cut sections and embankments in such manner that their surfaces have at all times a sufficient minimum crossfall and, where practicable, a sufficient longitudinal gradient to enable them to shed water and prevent ponding.

The works involved in keeping the earthwork or any other item of works free of water shall be deemed as incidental to the respective item of work and as such no separate payment shall be made for the same.

5A.3.25. Site Filling

5A.3.25.1 Sand fill

Sandy fill shall be deposited to bring the grade level to the desired elevation after compaction of fill. Sandy fill shall be carried out in one of the following methods as detailed in the drawings:

Compaction of sandy fill by flooding the area shall be carried out where so specified. In this case, Contractor should ensure that the fill material is not washed away. This work shall be carried out as directed by Engineer.

Sandy fill shall be compacted where so specified by 12 tonne vibrating rollers. The fill material shall be compacted to the required density.

If the density of fill or use of rollers for compaction is not specified, Contractor shall ensure necessary compaction by the passage of trucks, carrying the fill material over the deposited fill in such a way that the entire fill area is covered. This will reasonably compact the sand fill and will be accepted by Engineer. However, Contractor shall ensure that every layer is thus compacted before the succeeding layers are deposited. Each layer shall not exceed 200mm in thickness.

5A.3.25.2 Soil fill

Approved soil fill consisting of ordinary soil, murrum, soil containing gravel, shingle, etc. shall be deposited in layers not exceeding 200mm. Contractor should ensure that all clods of earth are broken down to a size not larger than 100mm.

Where density of fill or use of rollers is not specified, the fill shall be carried out as specified above.

Where specified, the required density to fill shall be obtained by proper compaction.

Chapter – 5A.4

5A.4 - CONCRETE AND ALLIED WORKS

5A.4.1. Applicable Codes

5A.4.1.1 Materials

1) IS: 269 Specification for 33 grade ordinary Portland cement.
2) IS: 383 Specification for coarse and fine aggregates from natural sources for concrete.
3) IS: 432 Specification for mild steel and medium (tensile steel bars and hard- drawn steel) wires for concrete reinforcement. (Part 1 and 2)
4) IS: 455 Specification for Portland slag cement.
5) IS: 1489 Specification for Portland-pozzolana cement (Part 1&2).
6) IS: 1566 Specification for hard-drawn steel wire fabric for concrete reinforcement.
7) IS: 1786 Specification for high strength deformed steel bars and wires for concrete reinforcement.
8) IS: 2645 Specification for integral cement water- proofing compounds.
9) IS: 4990 Specification for plywood for concrete shuttering
10) IS: 8112 Specification for 43 grade ordinary Portland cement.
11) IS: 9103 Specification for admixtures for concrete work.
12) IS: 12269 Specification for 53 grade ordinary Portland cement.
13) IS: 12330 Specification for sulphate resisting Portland cement.

5A.4.1.2 Material Testing

1) IS: 650 Specification for standard sand for testing of cement
2) IS: 2430 Methods for sampling of aggregates for concrete.
3) IS.2386 Methods of test for aggregates for concrete (Parts 1 to 8)
4) IS: 3025 Methods of sampling and test (physical and chemical) for water used in industry.
5) IS.4031 Methods of physical tests for hydraulic cement (Parts 1 to 15)
6) IS: 4032 Method chemical analysis of hydraulic cement. .

7) IS: 6925 Methods of test for determination of water soluble chlorides in concrete admixtures.

5A.4.1.3 Material Storage

1) IS: 4082 Recommendations on stacking and storing of construction materials at site

5A.4.1.4 Concrete Mix Design

1) IS: 10262 Recommended guidelines for concrete mix design.

2) SP: 23 (S&T) Handbook on Concrete Mixes.

5A.4.1.5 Concrete Testing

1) IS: 516 Method of test for strength of concrete.

2) IS.1199 Method of sampling and analysis of concrete.

3) IS: 2770 Methods of testing bond in reinforced concrete.

4) IS: 8142 Method of test for determining setting time of concrete by resistance.

5) IS: 9013 Method of making, curing and determining compressive strength of accelerated cured concrete test specimens.

6) IS: 9284 Method of test for abrasion resistance of concrete.

5A.4.1.6 Equipments

1) IS: 1791 Specification for batch type concrete mixers.

2) IS: 2438 Specification for roller pan mixer.

3) IS: 2505 General Requirements for concrete vibrators: Immersion type.

4) IS: 2506 General Requirements for screed board concrete vibrators.

5) IS: 2514 Specification for concrete vibrating tables.

6) IS: 2722 Specification for portable swing weigh batchers for concrete (single and double bucket type).

7) IS: 2750 Specification for steel scaffoldings.

8) IS: 4925 Specification for concrete batching and mixing plant.

9) IS: 4656 Specification for form vibrators for concrete.

10) IS: 5892 Specification for concrete transit mixer and agitator.

11) IS: 7242 Specification for concrete spreaders.

12) IS: 7251 Specification for concrete finishers.

13) IS: 11993 Code of practice for use of screed board concrete vibrators.

5A.4.1.7 Codes of Practice

1) IS: 456 Code of practice for plain and reinforced concrete.

2) IS: 457 Code of practice for general construction of plain and reinforced concrete for dams and other massive structures.

3) IS: 2204 Code of practice for construction of reinforced concrete shell roof.

4) IS: 2210 Criteria for the design of reinforced concrete shell structures and folded plates.

5) IS: 2502 Code of practice for bending and fixing of bars for concrete reinforcement.

6) IS: 2571 Code of practice for laying insitu cement concrete flooring.

7) IS: 2751 Code of practice for welding of mild steel plain and deformed bars used for reinforced concrete construction.

8) IS: 3370 (Parts 1 to 4) Code of practice for concrete structures for storage of liquids

9) IS: 3414 Code of practice for design and installation of joints in buildings.

10) IS: 3558 Code of practice for use of immersion vibrators for consolidating concrete.

11) IS: 3935 Code of practice for composite construction.

12) IS: 4014 Code of practice for steel tubular scaffolding (Parts 1 & 2)

13) IS: 4326 Code of practice for earthquake resistant design and construction of building.

14) IS: 5525 Recommendation for detailing of reinforcement in reinforced concrete works.

15) IS: 7861 Code of practice for extreme weather concreting: Part 1 Recommended practice for hot weather concreting.

16) IS: 9417 Specification for welding cold worked bars for reinforced concrete construction.

5A.4.1.8 Construction Safety

1) IS: 3696 (Parts 1 & 2) Safety code for scaffolds and ladders.

2) IS: 7969 Safety code for handling and storage of building materials.

3) IS: 8989 Safety code for erection of concrete framed structures.

5A.4.2. General

The Engineer shall have the right at all times to inspect all operations including the sources of materials, procurement, layout and storage of materials, the concrete batching and mixing equipment and the quality control system. Such an inspection shall be arranged and the Engineer's approval obtained, prior to starting of concrete work. This shall, however, not relieve the Contractor of any of his responsibilities. All materials which do not conform to the Specifications shall be rejected.

Materials should be selected so that they can satisfy the design requirements of strength, serviceability, safety, durability and finish with due regards to the functional requirements and the environmental conditions to which the structure will be subjected. Materials complying with codes/standards shall generally be used. Other materials may be used after approval of the Engineer and after establishing their performance suitability based on previous data, experience or tests.

5A.4.3. Materials

5A.4.3.1 Cement

Unless otherwise called for by the Engineer, cement shall be ordinary Portland cement conforming to IS: 269, IS: 8112 or IS: 12269.

Where Portland pozzolana or slag cements are used, it shall be ensured that consistency of quality is maintained, there will be no adverse interactions between the materials and the finish specified is not marred.

Only one type of cement shall be used in any one mix. The source of supply, type or brand of cement within the same structure or portion thereof shall not be changed without approval from the Engineer.

Cement which is not used within 90 days from its date of manufacture shall be tested at a laboratory approved by the Engineer and until the results of such tests are found satisfactory, it shall not be used in any work.

5A.4.3.2 Aggregates (General)

Aggregates shall consist of naturally occurring stones (crushed or uncrushed), gravel and sand. They shall be chemically inert, strong, hard, clean, durable against weathering, of limited porosity, free from dust/silt/ organic impurities/deleterious materials and conform to IS: 383. Aggregates such as slag, crushed over burnt bricks, bloated clay ash, sintered fly ash and tiles shall not be used.

Aggregates shall be washed and screened before use where necessary or if directed by the Engineer.

Aggregates containing reactive materials shall be used only after tests conclusively prove that there will be no adverse effect on strength, durability and finish, including long term effects, on the concrete.

The fineness modulus of sand shall neither be less than 2.2 nor more than 3.2.

The maximum size of coarse aggregate shall be as stated on the drawings but in no case greater than 1/4 of the minimum thickness of the member.

Plums 160 mm and above of a reasonable size may be used in mass concrete fill where directed. Plums shall not constitute more than 20% by volume of the concrete.

5A.4.3.3 Water

Water used for both mixing and curing shall conform to IS: 456. Potable waters are generally satisfactory. Water containing any excess of acid, alkali, sugar or salt shall not be used.

5A.4.3.4 Reinforcement

In general, reinforcement shall HYSD-415 conforming to IS:1786 and steel wire fabric to IS:1566 as shown or specified on the drawing.

All reinforcement shall be clean, free from pitting, oil, grease, paint, loose mill scales, rust, dirty, dust, or any other substance that will destroy or reduce bond.

5A.4.3.5 Admixtures

Accelerating, retarding, water-reducing and air entraining admixtures shall conform to IS: 9103 and integral water proofing admixtures to IS: 2645.

Admixtures may be used in concrete as per manufacturer's instructions only with the approval of the Engineer. An admixture's suitability and effectiveness shall be verified by trial mixes with the other materials used in the works. If two or more admixtures are to be used simultaneously in the same concrete mix, their interaction shall be checked and trial mixes done to ensure their compatibility. There should also be no increase in risk of corrosion of the reinforcement or other embedment.

Calcium chloride shall not be used for accelerating set of the cement for any concrete containing reinforcement or embedded steel parts. When calcium chloride is permitted such as in mass concrete works, it shall be dissolved in water and added to the mixing water by an amount not exceeding 1.5 percent of the weight of the cement in each batch of concrete. The designed concrete mix shall be corrected accordingly.

5A.4.4. Wastage

Wastage allowance for cement and steel and higher rolling margin for steel shall be considered in the item rate and no extra payment shall become payable to the Contractor on any account.

5A.4.5. Samples and Tests

All materials used for the works shall be tested before use. Manufacturer's test certificate shall be furnished for each batch of cement/steel and when directed by the Engineer samples shall also be got tested by the Contractor in a laboratory approved by the Engineer at no extra cost to Employer. Sampling and testing shall be as per IS:2386 under the supervision of the Engineer. Water to be used shall be tested to comply with requirements of IS:456.

The Contractor shall furnish manufacturer's test certificates and technical literature for the admixture proposed to be used. If directed, the admixture shall be got tested at an approved laboratory at no extra cost.

5A.4.6. Storing of Materials

All materials shall be stored in a manner so as to prevent its deterioration and contamination which would preclude its use in the works. Requirements of IS: 4082 shall be complied with.

The Contractor will have to make his own arrangements for the storage of adequate quantity of cement. If such cement is not stored properly and has deteriorated, the material shall be rejected. Cement bags shall be stored in dry weatherproof shed with a raised floor, well away from the outer walls and insulated from the floor to avoid moisture from ground. Not more than 15 bags shall be stacked in any tier. Storage arrangement shall be approved by the Engineer. Storage under tarpaulins shall not be permitted. Each consignment of cement shall be stored separately and consumed in its order of receipt.

Each size of coarse and fine aggregates shall be stacked separately and shall be protected from leaves and contamination with foreign material. The stacks shall be on hard, clean, free draining bases, draining away from the concrete mixing area.

The Contractor shall make his own arrangements for storing water at site in tanks to prevent contamination.

The reinforcement shall be stacked on top of timber sleepers to avoid contact with ground/water. Each type and size shall be stacked separately.

5A.4.7. Concrete

5A.4.7.1 General

Concrete grade shall be as designated on drawings. In concrete grade M15, M20 etc. the number represents the specified characteristic compressive strength of 150 mm cube at 28 days, expressed in N/sq.mm as per IS:456. Concrete in the works shall be "DESIGN MIX CONCRETE" or "NOMINAL MIX CONCRETE". All concrete works of grade M10 and M15 shall be NOMINAL MIX CONCRETE whereas all other grades, M20 and above, shall be DESIGN MIX CONCRETE.

The grades of concrete to be used are noted on the drawings. In addition, the following table shall apply unless specified otherwise.

Structure	Grade of Concrete	Max. Aggregate Size

1. All Reservoir works / liquid retaining structures / intake structures / box culverts, etc.	M25	20 mm
2. Pumping Station (a) for foundation raft (b) for walls, columns, floor beams, circular floor slab (c) for beams, slabs etc.	 M20 M20 M20	 40 mm 20 mm 20 mm
3. Valve chambers and pipe trenches (a) for foundation raft (b) walls, columns (c) for slabs, beams, etc.	 M20 M20 M20	 40 mm 20 mm 20 mm
4. Anchor blocks on pipeline, base slab of storm water drain	M15	40 mm
5. Saddles	M20	20 mm
6. Pipeline embankment, grade slab, ramps, footings under walls, SW drain coping etc	M15	20 mm
7. Causeway	M20	20 mm

5A.4.7.2 Design Mix Concrete

Mix Design & Testing

For Design Mix Concrete, the mix shall be designed according to IS: 10262 and SP: 23 to provide the grade of concrete having the required workability and characteristic strength not less than appropriate values given in IS: 456. The design mix shall in addition be such that it is cohesive and does not segregate and should result in a dense and durable concrete and also capable of giving the finish as specified. For liquid retaining structures, the mix shall also result in water tight concrete. The Contractor shall exercise great care while designing the concrete mix and executing the works to achieve the desired result.

The minimum cement content for Design Mix Concrete shall be as per Appendix-A of IS: 456 or as given below, whichever is higher.

Grade of Concrete	Minimum Cement Content in Kg/Cu.m of Concrete
M20	315
M25	360
M30	360

The minimum cement content stipulated above shall be adopted irrespective of whether the Contractor achieves the desired strength with less quantity of cement. The Contractor's quoted rates for concrete shall provide for the above eventuality and nothing extra shall become payable to the Contractor in this account. Even in the case where the quantity of cement required is higher than that specified above to achieve desired strength based on an approved mix design, nothing extra shall become payable to the Contractor.

The Contractor shall submit details of the source of all material and the proposed quantities of each ingredient per cubic metre of fully compacted concrete. The Contractor shall then make trial mixes for each class of concrete using the same Contractor’s Equipment and the same materials as are proposed for the Permanent Works. The Contractor shall give 24 hours notice of such trials to enable the Engineer’s Representative to attend. For each trial mix, three separate batches of concrete shall be made by the Contractor and will be tested at 28 days all in accordance with IS: 516. Such trial mixes shall not be the first batch through the plant in any one sequence of concrete production. The Contractor shall not commence concreting in the Permanent Works until details of trial mixes and test results for each class of concrete have been submitted to and approved by the Engineer.

Unless otherwise specified, only medium graded fine aggregate shall be used

A trial mix design will be approved by the Engineer with respect to strength if the average compressive strength of the nine cubes so tested is more than the target mean strength appropriate to the grade of concrete.

For concrete of Grade 30 and over the Contractor shall cast two sample wall panels 48 hours apart. Each shall be cast in two equal lifts to form a wall panel having one horizontal construction joint formed in the manner proposed by the Contractor for the Works. The top surface of the second lift shall have a Type U3 finish. The panels shall not be touched up after stripping. The panels shall be 300 mm thick and 1.5 m long by 1.5 m high. The Contractor shall not commence concreting in the Permanent Works until the test panels have been approved by Engineer.

The Contractor shall not alter the approved mix proportions nor the approved source of supply of any of the ingredients without having previously obtained the approval of the Engineer.

During production, the Engineer may require trial mixes to be made before a substantial change is made in the materials or in the proportions of the materials to be used.

It shall be the Contractor's sole responsibility to carry out the mix designs at his own cost. He shall furnish to the Engineer at least 30 days before concreting operations, a statement of proportions proposed to be used for the various concrete mixes and the strength results obtained. The strength requirements of the concrete mixes ascertained on 150 mm cubes as per IS:516 shall comply with the requirements of IS:456 as follows :

Grade of Concrete	Minimum Compressive Strength N/sq.mm at 7 days	Specified Characteristic Compressive Strength N/sq.mm at 28 days
M 15	10.0	15.0
M 20	13.5	20.0
M 25	17.0	25.0
M 30	20.0	30.0
M 35	23.5	35.0
M 40	27.0	40.0

A range of slumps which shall generally be used for various types of construction unless otherwise instructed by the Engineer is given below:

Structure/Member	Slump in millimeters	
	Maximum	Minimum
Reinforced foundation walls and footings	75	40
Plain footings, caissons and substructure walls	75	40
Slabs, Beams and reinforced walls	100	40
Pump & miscellaneous Equipment Foundation	75	40
Building columns	100	40
Pavements	50	40
Heavy mass construction	50	40

Note: All concreting done for water retaining structures shall have a minimum slump value of 60 mm and maximum of 100 mm

Batching & Mixing of Concrete

It is expected that batching plants of minimum 20 m^3 capacity and pumps for placing concrete shall be used. Proportions of aggregates and cement, as decided by the concrete mix design, shall be by weight. These proportions shall be maintained during subsequent concrete batching by means of weigh batchers capable of controlling the weights within one percent of the desired value.

Amount of water added shall be such as to produce dense concrete of required consistency, specified strength and satisfactory workability and shall be so adjusted to account for moisture content in the aggregates. Water- cement ratio specified for use by the Engineer shall be maintained. Each time the work stops, the mixer shall be cleaned out, and while recommencing, the first batch shall have 10% additional cement to allow for sticking in the drum.

Arrangement should be made by the Contractor to have the cubes tested in an approved laboratory or in field with prior consent of the Engineer. Sampling and testing of strength and workability of concrete shall be as per IS:1199, IS:516 and IS:456.

5A.4.8. Nominal Mix Concrete

Mix Design & Testing

Mix design and preliminary tests are not necessary for Nominal Mix Concrete. However works tests shall be carried out as per IS:456. Proportions for Nominal Mix Concrete and w/c ratio may be adopted as per Table 3 of IS:456. However it will be the Contractor's sole responsibility to adopt appropriate nominal mix proportions to yield the specified strength.

Batching & Mixing of Concrete

Based on the adopted nominal mixes, aggregates shall be measured by volume. However cement shall be by weight only, using whole bags of cement.

5A.4.9. Formwork

Formwork shall be all inclusive and shall consist of but not be limited to shores, bracings, sides of footings, walls, beams and columns, bottom of slabs etc. including ties, anchors, hangers, inserts, false work, wedges etc.

The design and engineering of the formwork as well as its construction shall be the responsibility of the Contractor. However, if so desired by the Engineer, the drawings and calculations for the design of the formwork shall be submitted to the Engineer for approval.

Formwork shall be designed to fulfill the following requirements :

(a) Sufficiently rigid and tight to prevent loss of grout or mortar from the concrete at all stages and appropriate to the methods of placing and compacting.

(b) Made of suitable materials.

(c) Capable of providing concrete of the correct shape and surface finish within the specified tolerance limits.

(d) Capable of withstanding without deflection the worst combination of selfweight, reinforcement and concrete weight, all loads and dynamic effects arising from construction and compacting activities, wind and weather forces.

(e) Capable of easily striking without shock, disturbance or damage to the concrete.

(f) Soffit forms capable of imparting a camber if required.

(g) Soffit forms and supports capable of being left in position if required.

(h) Capable of being cleaned and/or coated if necessary immediately prior to casting the concrete; design temporary openings where necessary for these purposes and to facilitate the preparation of construction joints.

The formwork may be of timber, plywood, steel, plastic or concrete depending upon the type of finish specified. Sliding forms and slip form may be used with the approval of the Engineer. Timber for formwork shall be well seasoned, free from sap, shakes, loose knots, worm holes, warps and other surface defects. Joints between formwork and formwork and between formwork and structures shall be sufficiently tight to prevent loss of slurry from concrete, using seals if necessary.

The faces of formwork coming in contact with concrete shall be cleaned and two coats of approved mould oil applied before fixing reinforcement. All rubbish, particularly chippings, shavings, sawdust, wire pieces dust etc. shall be removed from the interior of the forms before the concrete is placed. Where directed, cleaning of forms shall be done by blasting with a jet of compressed air at no extra cost.

Forms intended for reuse shall be treated with care. Forms that have deteriorated shall not be used. Before reuse, all forms shall be thoroughly scraped, cleaned, nails removed, holes suitably plugged, joints repaired and warped lumber replaced to the satisfaction of the Engineer. The Contractor shall equip himself with enough shuttering to allow for wastage so as to complete the job in time.

Permanent formwork shall be checked for its durability and compatibility with adjoining concrete before it is used in the structure. It shall be properly anchored to the concrete.

Wire ties passing through beams, columns and walls shall not be allowed. In their place bolts passing through sleeves shall be used. Formwork spacers left insitu shall not impair the desired appearance or durability of the structure by causing spalling, rust staining or allowing the passage of moisture.

For liquid retaining structures, sleeves shall not be provided for through bolts nor shall through bolts be removed if provided. The bolts, in the latter case, shall be cut at 25 mm depth from the surface and the hole made good by cement mortar of the same proportion as the concrete just after striking the formwork.

All corners and angles exposed in the finished structure shall have chamfers or fillets of 20 mm x 20 mm size, except where specified in the drawings.

Forms for substructure may be omitted when, in the opinion of the Engineer, the open excavation is firm enough (in hard non-porous soils) to act as a form. Such excavations shall be larger, as approved by the Engineer, than that required as per drawing to compensate for irregularities in excavation.

The Contractor shall provide adequate props carried down to a firm bearing without overloading any of the structures.

The shuttering for beams and slabs shall be so erected that the side shuttering of beams can be removed without disturbing the bottom shuttering. If the shuttering for a column is erected for the full height of the column, one side shall be built up in sections as placing of concrete proceeds or windows left for placing concrete from the side to limit the drop of concrete to 1.0m or as approved by the

Engineer. The Contractor shall temporarily and securely fix items to be cast (embedments/ inserts) in a manner that will not hinder the striking of forms or permit loss of grout.

Formwork showing excessive distortion, during any stage of construction, shall be repositioned and strengthened. Placed concrete affected by faulty formwork, shall be entirely removed and formwork corrected prior to placement of new concrete at Contractor’s cost.

The striking time for formwork shall be determined based on the following requirements :

1. Development of adequate concrete strength;
2. Permissible deflection at time of striking form work;
3. Curing procedure employed - its efficiency and effectiveness;
4. Subsequent surface treatment to be done;
5. Prevention of thermal cracking at re-entrant angles;
6. Ambient temperatures; and
7. Aggressiveness of the environment (unless immediate adequate steps are taken to prevent damage to the concrete).

Under normal circumstances (generally where temperatures are above 20^{o}C) forms may be struck after expiry of the time period given in IS:456 unless approved otherwise by the Engineer. For Portland Pozzolana/slag cement the stripping time shall be suitably modified as approved by the Engineer. It is the Contractor's responsibility to ensure that forms are not struck until the concrete has developed sufficient strength to support itself, does not undergo excessive deformation and resist surface damage and any stresses arising during the construction period.

5A.4.10. Reinforcement Workmanship

Reinforcing bars supplied bent or in coils shall be straightened cold without damage. No bending shall be done when ambient temperature is below 5^{o}C. Local warming may be permitted if steel is kept below 100^{o} C.

All bars shall be accurately bent gradually and according to the sizes and shapes shown on the drawings/ schedules or as directed by the Engineer.

Re-bending or straightening incorrectly bent bars shall not be done without the approval of the Engineer.

Reinforcement shall be accurately fixed and maintained firmly in the correct position by the use of blocks, spacers, chairs, binding wire etc. to prevent displacement during placing and compaction of concrete. The tied in place reinforcement shall be approved by the Engineer prior to concrete placement. Spacers shall be of such materials and designs as will be durable, not lead to corrosion of the reinforcement and not cause spalling of the concrete cover.

Binding wire shall be 16 gauge soft annealed wire. Ends of the binding wire shall be bent away from the concrete surface and in no case encroach into the concrete cover.

Substitution of reinforcement, laps/splices not shown on drawing shall be subject to Engineer's approval.

5A.4.11. Tolerances

Tolerance is a specified permissible variation from lines, grade or dimensions given in drawings. No tolerance specified for horizontal or vertical building lines or footings shall be construed to permit encroachment beyond the legal boundaries. Tolerance for formed and concrete dimensions shall be as per IS:456 unless specified otherwise.

5A.4.11.1 Tolerances for R.C. Buildings

Variation from the Plumb

(i) In the lines and surfaces of columns, piers, walls and in arrises 5 mm per 2.5 m or 25 mm, whichever is less.

(ii) For exposed corner columns and other conspicuous lines

In any bay or 5 m maximum	-	5 mm
In 10 m or more	-	10 mm

Variation from the level or from the grades indicated on the drawings

(i) In slab soffits, ceilings, beam soffits, and in arises

In 2.5 m	-	5 mm
In any bay or 5 m maximum	-	10 mm
In 10 m or more	-	15 mm

(ii) For exposed lintels, sills, parapets, horizontal grooves and other conspicuous lines :

In any bay or 5 m maximum	-	5 mm
In 10 m or more	-	10 mm

Variation of the linear building lines from established position in plan and related position of columns, wall and partitions :

In any bay or 5 m maximum	-	10 mm
In 10 m or more	-	20 mm

Variation in the sizes and locations of sleeves, openings in walls and floors – 5 mm except in the case of and for anchor bolts.

Variation in cross-sectional dimensions of columns and beams and in the thickness of slabs and walls

Minus - 5 mm

Plus - 10 mm

Footings

(i) Variation in dimension in plan

Minus - 5 mm

Plus - 50 mm

(ii) Misplacement or eccentricity

2% of footing width in the direction of misplacement but not more than 50 mm

(iii) Reduction in thickness

Minus - 5% of specified thickness subject to a maximum of 50 mm

Variation in steps

(i) In a flight of stairs

Rise - 3 mm

Tread - 5 mm

(ii) In consecutive steps

Rise - 1.5 mm

Tread - 3.0 mm

5A.4.11.2 Tolerances in other structures

All structures

(i) Variation of the construction linear outline from established position in plan

In 5 m - 10 mm

In 10 m or more - 15 mm

(ii) ... Variations of dimensions to individual structure features from established positions

In 20 m or more - 25 mm

In buried construction - 50 mm

(iii)................ Variation from plumb, from specified batter or from curved surfaces of all structures

In 2.5 m	-	10 mm
In 5 m	-	15 mm
In 10 m or more	-	25 mm
In buried construction	-	Twice the above amounts

(iv) Variation from level or grade indicated on drawings in slab, beams, soffits, horizontal grooves and visible arises.

In 2.5 m	-	5 mm
In 7.5 m or more	-	10 mm
In buried construction	-	Twice the above amounts

(v) Variation in cross-sectional dimensions of columns, beams, buttresses, piers and similar members

Minus	-	5 mm
Plus	-	10 mm

(vi) ....Variation in the thickness of slabs, walls, arch sections and similar members

Minus	-	5 mm
Plus	-	10 mm

Footing for columns, piers, walls, buttresses and similar members

(i) Variation of dimension in plan

Minus	-	10 mm
Plus	-	50 mm

(ii) Misplacement or eccentricity

2% footing width in the direction of misplacement but not more than 50 mm

(iii) Reduction in thickness

5% of specified thickness subject to a maximum of 50 mm.

5A.4.11.3 Tolerance in fixing anchor bolts shall be as follows :

(i) Anchor bolts without sleeves : 1.5 mm in plan

(ii) Anchor bolts with sleeves : 5.0 mm in elevation

- for bolts upto and including 28 mm dia : 5 mm in all directions
- for bolts 32 mm dia and above : 3 mm in all directions

(iii) Embedded parts : 5 mm in all directions

5A.4.11.4 Tolerances in Formwork:

The formwork shall be designed and constructed to the shapes, lines and dimensions shown on the drawings within the tolerances given below:

(i)	Deviation from specified dimensions of cross section of columns and beams	- 6 mm + 12 mm
(ii)	Deviations from dimensions of footings (Tolerances apply to concrete dimensions only, not to positioning of vertical reinforcing steel or dowels)	
	- Dimension in plan	- 12 mm + 50 mm
	- Eccentricity	0.02 times the width of the footing in the direction of deviation but not more than 50 mm
	- Thickness	± 0.05 times the specified thickness

5A.4.12. Preparation Prior to Concrete Placement

Before concrete is actually placed in position, the inside of the formwork shall be cleaned and mould oil applied, inserts and reinforcement shall be correctly positioned and securely held, necessary openings, pockets, etc. provided.

All arrangements-formwork, equipment and proposed procedure, shall be approved by the Engineer. Contractor shall maintain separate Pour Card for each pour as per the format enclosed.

5A.4.13. Transporting, Placing and Compacting Concrete

Concrete shall be transported from the mixing plant to the formwork with minimum time lapse by methods that shall maintain the required workability and will prevent segregation, loss of any ingredients or ingress of foreign matter or water.

In all cases concrete shall be deposited as nearly as practicable directly in its final position. To avoid segregation, concrete shall not be rehandled or caused to flow. For locations where direct placement is not possible and in narrow forms the Contractor shall provide suitable drops and "Elephant Trunks". Concrete shall not be dropped from a height of more than 1.0m as stipulated in clause 4.8.

Concrete shall not be placed in flowing water. Under water, concrete shall be placed in position by tremies or by pipeline from the mixer and shall never be allowed to fall freely through the water.

While placing concrete the Contractor shall proceed as specified below and also ensure the following:

a) Continuously between construction joints and pre- determined abutments.
b) Without disturbance to forms or reinforcement.
c) Without disturbance to pipes, ducts, fixings and the like to be cast in; ensure that such items are securely fixed. Ensure that concrete cannot enter open ends of pipes and conduits etc.
d) Without dropping in a manner that could cause segregation or shock.
e) In deep pours only when the concrete and formwork designed for this purpose and by using suitable chutes or pipes.
f) Do not place if the workability is such that full compaction cannot be achieved.
g) Without disturbing the unsupported sides of excavations; prevent contamination of concrete with earth. Provide sheeting if necessary. In supported excavations, withdraw the linings progressively as concrete is placed.
h) If placed directly onto hardcore or any other porous material, dampen the surface to reduce loss of water from the concrete.
i) Ensure that there is no damage or displacement to sheet membranes.
j) Record the time and location of placing structural concrete.

Concrete shall normally be compacted in its final position within thirty minutes of leaving the mixer. Concrete shall be compacted during placing with approved vibrating equipment without causing segregation until it forms a solid mass free from voids thoroughly worked around reinforcement and embedded fixtures and into all corners of the formwork. Immersion vibrators shall be inserted vertically at points not more than 450 mm apart and withdrawn slowly till air bubbles cease to come to the surface, leaving no voids. When placing concrete in layers advancing horizontally, care shall be taken to ensure adequate vibration, blending and melding of the concrete between successive layers. Vibrators shall not be allowed to come in contact with reinforcement, formwork and finished surfaces after start of initial set.

Concrete may be conveyed and placed by mechanically operated equipment after getting the complete procedure approved by the Engineer. The slump shall be held to the minimum necessary for conveying concrete by this method. When concrete is to be pumped, the concrete mix shall be specially designed to suit pumping. Care shall be taken to avoid stoppages in work once pumping has started.

Except when placing with slip forms, each placement of concrete in multiple lift work, shall be allowed to set for at least 24 hours after the final set of concrete before the start of subsequent placement. Placing shall stop when concrete reaches the top of the opening in walls or bottom surface of slab, in slab and beam construction, and it shall be resumed before concrete takes initial set but not until it has had time to settle as approved by the Engineer. Concrete shall be protected against damage until final acceptance.

5A.4.14. Mass Concrete Works

Sequence of pouring for mass concrete works shall be as approved by the Engineer. The Contractor shall exercise great care to prevent shrinkage cracks and shall monitor the temperature of the placed concrete if directed.

5A.4.15. Curing

Curing and protection shall start immediately after the compaction of the concrete to protect it from:

a) Premature drying out, particularly by solar radiation and wind;

b) Leaching out by rain and flowing water;

c) Rapid cooling during the first few days after placing;

d) High internal thermal gradients;

e) Low temperature or frost;

f) Vibration and impact which may disrupt the concrete and interfere with its bond to the reinforcement.

All concrete, unless approved otherwise by the Engineer, shall be cured by use of continuous sprays or ponded water or continuously saturated coverings of sacking, canvas, hessain or other absorbent material for the period of complete hydration with a minimum of 7 days. The quality of curing water shall be the same as that used for mixing.

Where a curing membrane is approved to be used by the Engineer, the same shall be of a non-wax base and shall not impair the concrete finish in any manner. The curing compound to be used shall be approved by the Engineer before use and shall be applied with spraying equipment capable of a smooth, even textured coat.

Curing may also be done by covering the surface with an impermeable material such as polyethylene, which shall be well sealed and fastened.

5A.4.16. Construction Joints and Keys

Construction joints will be as shown on the drawing or as approved by the Engineer. Concrete shall be placed without interruption until completion of work between construction joints. If stopping of concreting becomes unavoidable anywhere, a properly formed construction joint shall be made with the approval of the Engineer.

Dowels for concrete work, not likely to be taken up in the near future, shall be coated with cement slurry and encased in lean concrete as indicated on the drawings or as approved by the Engineer.

As soon as the exposed concrete has sufficiently hardened, the surface of the joint shall be water jetted or brushed with a stiff brush to expose the larger aggregate without being disturbed. Roughening of the surface by chipping or hacking will not generally be approved. Before placing fresh concrete against a construction joint all loose material shall be removed and the surface sluiced with water until it is perfectly clean, thereafter all ponded water should be removed.

When concreting is to be resumed on a surface which has not fully hardened, all laitance shall be removed by wire brushing, the surface wetted, free water removed and a coat of cement slurry applied. On this, a layer of concrete not exceeding 150 mm thickness shall be placed and well rammed against the old work. Thereafter work shall proceed in the normal way.

5A.4.17. Foundation Bedding

All earth surfaces upon which or against which concrete is to be placed, shall be well compacted and free from standing water, mud or debris. Soft or spongy areas shall be cleaned out and back filled with either soil-cement mixture, lean concrete or clean sand compacted as approved by the Engineer. The surfaces of absorptive soils shall be moistened.

Concrete shall not be deposited on large sloping rock surfaces. The rock shall be cut to form rough steps or benches by picking, barring or wedging. The rock surface shall be kept wet for 2 to 4 hours before concreting.

5A.4.18. Finishes

5A.4.18.1 General

The formwork for concrete works shall be such as to give the finish as specified. The Contractor shall make good any unavoidable defects as approved consistent with the type of concrete and finish specified; defects due to bad workmanship (e.g. damaged or misaligned forms, defective or poorly compacted concrete) will not be accepted. The Contractor shall construct the formwork using the correct materials and to meet the requirements of the design and to produce finished concrete to required dimensions, plumbs, planes and finishes.

5A.4.18.2 Surface Finish Type F1

The main requirement is that of dense, well compacted concrete. No treatment is required except repair of defective areas, filling all form tie holes and cleaning up of loose or adhering debris. For surfaces below grade which will receive waterproofing treatment the concrete shall be free of surface irregularities which would interfere with proper and effective application of waterproofing material specified for use.

5A.4.18.3 Surface Finish Type F2

The appearance shall be that of a smooth dense, well- compacted concrete showing the slight marks of well fitted shuttering joints. The Contractor shall make good any blemishes.

5A.4.18.4 Surface Finish Type F3

This finish shall give an appearance of smooth, dense, well-compacted concrete with no shutter marks, stain free and with no discolouration, blemishes, arises, airholes etc. Only lined or coated plywood with very tight joints shall be used to achieve this finish. The panel size shall be uniform and as large as practicable. Any minor blemishes that might occur shall be made good by the Contractor.

5A.4.18.5 Unformed Surfaces

Finishes to unformed surfaces of concrete shall be classified as U1, U2, and U3, ‘spaded or bonded concrete’. Where the class of finish is not specified the concrete shall be finished to Class U1.

Class U1 finish is the first stage for Class U2 and U3 finishes and for a bonded concrete surface. Class U1 finish shall be a levelled and screeded, uniform plain or ridged finish which (unless it is being converted to Class U2, U3, or bonded concrete) shall not be disturbed in any way after the initial set and during the period of curing, surplus concrete being struck off immediately after compaction.

Where a bonded concrete surface is specified, the laitance shall be removed from the Class U1 finished surface and the aggregate exposed while the concrete is still green.

A spaded finish shall be a surface free from voids and brought to a reasonably uniform appearance by the use of shovels as it is placed in the Works.

Class U2 finish shall be a wood float finish. Floating shall be done after the initial set of the concrete has taken place and the surface has hardened sufficiently. The concrete shall be worked no more than is necessary to produce a uniform surface free from screedmarks.

Class U3 finish shall be a hard smooth steel-trowelled finish. Trowelling shall not commence until the moisture film has disappeared and the concrete has hardened sufficiently to prevent excess laitance from being worked into the surface. The surfaces shall be trowelled under firm pressure and left free from trowel marks.

The addition of dry cement, mortar or water shall not be permitted during any of the above operations.

5A.4.18.6 Integral Cement Finish on Concrete Floor

In all cases where integral cement finish on a concrete floor has been specified, the top layer of concrete shall be screeded off to proper level and tamped with tamper so that the aggregate shall be forced below the surface. The surface shall be finished with a wooden float and a trowel with pressure. The finish shall be continued till the concrete reaches its initial set. No cement or cement mortar finish shall be provided on the surface. Where specified, a floor hardener as approved by the Engineer shall be supplied and used as recommended by the manufacturer.

5A.4.19. Repair and Replacement of Unsatisfactory Concrete

Immediately after the shuttering is removed, all the defective areas such as honey-combed surfaces, rough patches, holes left by form bolts etc. shall be inspected by the Engineer who may permit patching of the defective areas or reject the concrete work.

All through holes for shuttering shall be filled for full depth and neatly plugged flush with surface.

Rejected concrete shall be removed and replaced by the Contractor at no additional cost to the Employer. For patching of defective areas all loose materials shall be removed and the surface shall be prepared as approved by the Engineer.

Bonding between hardened and fresh concrete shall be done either by placing cement mortar with approved bonding agent or by applying epoxy. The decision of the Engineer as to the method of repairs to be adopted shall be final and binding on the Contractor. The surface shall be saturated with water for 24 hours before patching is done with 1:5 cement sand mortar. The use of epoxy for bonding fresh concrete shall be carried out as approved by the Engineer.

All the form bolt repairs and delayed repairs shall be carried out using a proportion of white cement in repair mix to the approval of the Engineer, so as to match the colour of the surrounding area.

5A.4.20. Vacuum Dewatering of Slabs

Where specified floor slabs, either grade or suspended, shall be finished by vacuum dewatering including all operations such as poker vibration, surface vibration, vacuum processing, floating and trowelling as per equipment manufacturers recommendation. The equipment to be used shall be subject to the Engineer's approval.

5A.4.21. Hot Weather Requirements

Concreting during hot weather shall be carried out as per IS:7861 (Part I).

Adequate provisions shall be made to lower concrete temperatures which shall not exceed 33^{o} C at the time of placement of fresh concrete.

Where directed by the Engineer, the Contractor shall spray non-wax based curing compound on unformed concrete surfaces at no extra costs.

5A.4.22. Liquid Retaining Structures

The Contractor shall take special care for concrete for liquid retaining structures, underground structures and those others specifically called for to guarantee the finish and water tightness.

The minimum level of surface finish for liquid retaining structures shall be Type F2. All such structures shall be hydro-tested.

The Contractor shall make all arrangements for hydro-testing of structure, all arrangements for testing such as temporary bulk heads, pressure gauges, pumps, pipe lines etc.

Any temporary arrangements that may have to be made to ensure stability of the structures shall also be considered to have been taken into account while quoting the rates.

Any leakage that may occur during the hydro-test or subsequently during the defects liability period or the period for which the structure is guaranteed shall be effectively stopped either by cement/epoxy pressure grouting, guniting or such other methods as may be approved by the Engineer. All such rectification shall be done by the Contractor to the entire satisfaction of the Employer/Engineer at no extra cost to the Employer.

5A.4.23. Testing Concrete Structures for Leakage

Hydro-static test for water tightness shall be done at full storage level or soffit of cover slab, as may be directed by the Engineer, as described below :

In case of structures whose external faces are exposed, such as elevated tanks, the requirements of the test shall be deemed to be satisfied if the external faces show no sign of leakage or sweating and remain completely dry during the period of observation of seven days after allowing a seven day period for absorption after filling with water.

In the case of structures whose external faces are buried and are not accessible for inspection, such as underground tanks, the structures shall be filled with water and after the expiry of seven days after the filling, the level of the surface of the water shall be recorded. The level of water shall be recorded again at subsequent intervals of 24 hrs. over a period of seven days. Backfilling shall be withheld till the tanks are tested. The total drop in surface level over a period for seven days shall be taken as an indication of the water tightness of the structure. The Engineer shall decide on the actual permissible nature of this drop in the surface level, taking into account whether the structures are open or closed and the corresponding effect it has on evaporation losses. Unless specified otherwise, a structure whose top is covered shall be deemed to be water tight if the total drop in the surface level over a period of seven days does not exceed 40 mm.

Each compartment/segment of the structure shall be tested individually.

For structures such as pipes, tunnels etc. the hydrostatic test shall be carried out by filling with water, after curing as specified, and subjecting to the specified test pressure for specified period. If during this period the loss of water does not exceed the equivalent of the specified rate, the structure shall be considered to have successfully passed the test.

5A.4.24. Optional Tests

If the Engineer is not satisfied with the results of the tests under Clause 4.5 or otherwise considers that the materials i.e. cement, sand, coarse aggregates, reinforcement and water are not in accordance with the Specifications or if specified concrete strengths are not obtained, he may order tests to be carried out on these materials in laboratory, to be approved by the Engineer, as per relevant IS Codes. Contractor shall have to pay for these tests.

In the event of any work being suspected of faulty material or workmanship requiring its removal or if the works cubes do not give the stipulated strengths, the Engineer reserves the right to order the Contractor to take out cores and conduct tests on them or do ultrasonic testing or load testing of structure, etc.The Engineer also reserves the right to ask the Contractor to dismantle and re-do such unacceptable work, at no cost to the Employer.

If the structure is certified as failed by Engineer, the cost of the test and subsequent dismantling/reconstruction shall be borne by the Contractor.

The quoted unit rates/prices of concrete shall be deemed to provide for all tests mentioned above.

5A.4.25. Grouting

5A.4.25.1 Standard Grout

Grout shall be provided as specified on the drawings. The proportion of Standard Grout shall be such as to produce a flowable mixture consistent with minimum water content and shrinkage. Surfaces to be grouted shall be thoroughly roughened and cleaned. All Structural steel elements to be grouted, shall be cleaned of oil, grease, dirt etc. The use of hot, strong caustic solution for this purpose will be permitted. Prior to grouting, the hardened concrete shall be saturated with water and just before grouting water in all pockets shall be removed. Grouting once started shall be done quickly and continuously. Variation in grout mixes and procedures shall be permitted if approved by Engineer. The grout proportions shall be limited as follows:

Use	Grout Thickness	Mix Proportions	W/C Ratio (max)
a) Fluid mix	Under 25mm	One part Portland Cement to one part sand	0.44
b) General mix	25mm and over but less than 50mm	One part Portland Cement to 2 parts of sand	0.53
c) Stiff mix	50mm and over	One part Portland Cement to 3 parts of sand	0.53

5A.4.25.2 Non-Shrink Grout

Non – shrink grout where required shall be provided in strict accordance with the manufacturer's instructions / specifications on the drawings.

5A.4.26. Inspection

All materials, workmanship and finished construction shall be subject to continuous inspection and approval of Engineer. Materials rejected by Engineer shall be expressly removed from site and shall be replaced by Contractor immediately.

5A.4.27. Clean-Up

Upon the completion of concrete work, all forms, equipment, construction tools, protective coverings and any debris, scraps of wood, etc. resulting from the work shall be removed and the premises left clean.

5A.4.28. Acceptance Criteria

Any concrete work shall satisfy the requirements given below individually and collectively for it to be acceptable.

a) Properties of constituent materials;

b) Characteristic compressive strength;

c) specified mix proportions;

d) Minimum cement content;

e) Maximum free-water/cement ratio;

f) Workability;

g) Temperature of fresh concrete;

h) Density of fully compacted concrete;

i) cover to embeded steel;

j) Curing;

k) Tolerances in dimensions;

l) Tolerances in levels;

m) Durability;

n) Surface finishes;

o) Special requirements such as;

    i) Water tightness

    ii) Resistance to aggressive chemicals

    iii) Resistance to freezing and thawing

    iv) Very high strength

    v) Improved fire resistance

    vi) Wear resistance

    vii) Resistance to early thermal cracking

The Engineer's decision as to the acceptability or otherwise of any concrete work shall be final and binding on the Contractor.

For work not accepted, the Engineer may review and decide whether remedial measures are feasible so as to render the work acceptable. The Engineer shall in that case direct the Contractor to undertake and execute the remedial measures. These shall be expeditiously and effectively implemented by the Contractor. Nothing extra shall become payable to the Contractor by the Employer for executing the remedial measures.

5A.4.29. Mode of Measurement and Payment

The unit rate for concrete work under various categories shall be all inclusive and no claims for extra payment on account of such items as leaving holes, embedding inserts, etc. shall be entertained unless separately provided for in the Schedule of Quantities. No extra claim shall also be entertained due to change in the number, position and/or dimensions of holes, slots or openings, sleeves, inserts or on account of any increased lift, lead of scaffolding etc. All these factors should be taken into consideration while quoting the unit rates. Unless provided for in the Schedule of Quantities the rates shall also include fixing inserts in all concrete work, whenever required.

Payments for concrete will be made on the basis of unit rates quoted for the respective items in the Schedule of Quantities. No deduction in the concrete quantity will be made for reinforcements, inserts etc. and opening less than 0.100 of a sqm and 0.010 cum where concrete is measured in cum. Where no such deduction for concrete is made, payment for shuttering work provided for such holes, pockets, etc. will not be made. Similarly the unit rates for concrete work shall be inclusive or exclusive of shuttering as provided for in the Schedule of Quantities.

Payment for beams will be made for the quantity based on the depth being reckoned from the underside of the slabs and length measured as the clear distance between supports. Payment for columns shall be made for the quantity based on height reckoned upto the underside of slabs/beams.

The unit rate for precast concrete members shall include formwork, mouldings, finishing, hoisting and setting in position including setting mortar, provision of lifting arrangement etc. complete. Reinforcement and inserts shall be measured and paid for separately under respective item rates.

Only the actual quantity of steel embedded in concrete including laps as shown on drawings or as approved by Engineer shall be measured and paid for, irrespective of the level or height at which the work is done. The unit rate for reinforcement shall include all wastages, binding wires, chairs, spacer bars etc. for which no separate payment shall be made.

Where the formwork is paid for separately, it shall be very clearly understood the payment for formwork is inclusive of formwork, shuttering, shoring, propping scaffolding etc. Only the net area of concrete formed(shuttered) shall be measured for payment.

5A.4.30. Water stops

5A.4.30.1 Material

The material for the PVC water stops shall be a plastic compound with the basic resin of polyvinyl chloride and additional resins, plasticizers, inhibitors, which satisfies the performance characteristics specified below as per IS:12200. Testing shall be in accordance with IS: 8543.

a) Tensile strength : 11.6 N/mm^2 minimum

b) Ultimate elongation : 300% minimum

c) Tear resistance : 4.9 N/mm^2 minimum

d) Stiffness in flexure : 2.46 N/mm^2 minimum

e) Accelerated extraction

  i) Tensile strength : 10.50 N/mm^2 minimum

  ii) Ultimate elongation : 250% minimum

(f) Effect of Alkali : 7 days

  i) Weight increase : 0.10% maximum

  ii) Weight decrease : 0.10% maximum

  iii) Hardness change : ± 5 points

(g) Effect of Alkali : 28 days

i) Weight increase : 0.40% maximum

ii) Weight decrease : 0.30% maximum

iii) Dimension change : ±1%

PVC water stops shall be either of the bar type, serrated with centre bulb and end grips for use within the concrete elements or of the surface (kicker) type for external use.

PVC water stops shall be of approved manufacture. Samples and the test certificate shall be got approved by the Engineer before procurement for incorporation in the works.

5A.4.30.2 Workmanship

Waterstops shall be cleaned before placing them in position. Oil or grease shall be removed thoroughly using water and suitable detergents.

Waterstops shall be procured in long lengths as manufactured to avoid joints as far as possible. Standard L or T type of intersection pieces shall be procured for use depending on their requirement. Any non-standard junctions shall be made by cutting the pieces to profile for jointing. Lapping of waterstops shall not be permitted. All jointing shall be of fusion welded type as per manufacturer's instructions.

Waterstops shall be placed at the correct location/level and suitably supported at intervals with the reinforcement to ensure that it does not deviate from its intended position during concreting and vibrating. **Particular care shall also be taken to ensure that no honey-combing occurs because of the serrations/end grips.** Projecting portions of the waterstops embedded in concrete shall be thoroughly cleaned of all mortar/ concrete coating before resuming further concreting operations. The projecting water stop shall also be suitably supported at intervals with the reinforcement to maintain its intended position during concreting so as to ensure that it does not bend leading to formation of pockets.

5A.4.31. Preformed Fillers and Joint Sealing Compound

5A.4.31.1 Materials

Preformed filler for expansion/isolation joints shall be non-extruding and resilient type of bitumen impregnated fibers conforming to IS: 1838 (Part I).

Bitumen coat to concrete/masonry surfaces for fixing the preformed bitumen filler strip shall conform to IS: 702. Bitumen primer shall conform to IS: 3384.

Sealants shall be of the following types:

Sealant Type B

Sealant type shall be a gun grade compound, suitable for sealing vertical movement and construction joints in concrete structures. It shall be flexible, resistant to aging, physical damage and weathering and shall have good adhesion to concrete.

Hardness (Shore A) : > 12

Transverse Movement Accommodation : ±12.5%

Sealant Type C

Sealant type C shall be similar to Type B above. In addition it shall have been designed for sealing movement and construction joints in hydraulic and water retaining structures and shall be suitable for use in contact with potable water.

Hardness (Shore A) : > 20

Transverse Movement Accommodation : ±12.5%

Sealant Type D

Sealant Type D shall be a pourable compound suitable for sealing horizontal movement and construction joints in concrete structures. It shall be flexible, resistant to aging, physical damage and weathering and shall have good adhesion to concrete.

Hardness (Shore A) : > 9

Transverse Movement Accommodation : ±12.5%

Sealant Type E

Sealant Type E shall be a cold pouring compound complying with BS 5212, suitable for sealing movement and construction joints in concrete paved areas. It shall be resistant to fuels, oils and hydraulic fluids. It shall be tough, abrasion-resistant and shall not decompose in strong sunlight.

Hardness (Shore A) : > 12

Transverse Movement Accommodation : ±12.5%

Approved Sealants

The following approved sealants meet the above specifications.

Sealant Type A, B and C : Thioflex 600 gun grade

Sealant Type D : Thioflex 600 pourable grade

Sealant Type E : Colpor 200

The hardness value specified in the above summaries is the Shore A Durometer value at 14 days at 25^{o} C and 50% RH. The specified transverse movement values are based on joints having a width to depth ratio of 1.5: 1. The Contractor may use the above sealants or ones meeting equivalent or higher specifications.

5A.4.31.2 Workmanship

The thickness of the preformed bitumen filler shall be 25mm for expansion joints and 50mm for isolation joints around foundation supporting rotatory equipments. Contractor shall procure the strips of the desired thickness and width in lengths as manufactured. Assembly of small pieces/thicknesses of strips to make up the specified size shall not be permitted.

The concrete/masonry surface shall be cleaned free from dust and any loose particles. When the surface is dry, one coat of industrial blown type bitumen of grade 85/25 conforming to IS:702 shall be applied hot by brushing at the rate of 1.20 kg/sq.m. When the bitumen is still hot the preformed bitumen filler shall be pressed and held in position till it completely adheres. The surface of the filler against which further concreting/masonry work is to be done shall similarly be applied with one coat of hot bitumen at the rate of 1.20 kg/sq.m. Sealing compound shall be heated to a pouring consistency for enabling it to run molten in a uniform manner into the joint. Before pouring the sealing compound, the vertical faces of the concrete joint shall be applied hot with a coat of bitumen primer conforming to IS:3384 in order to improve the adhesive quality of the sealing compound.Expansion joints between beams/slabs shall be provided with 100mm wide x 4mm thick mild steel plate at the soffit of RCC beams/slabs to support and prevent the preformed joint filler from dislodging. This plate shall be welded to an edge angle of ISA 50 x 50 x 6mm provided at the bottom corner, adjacent to the expansion joint of one of the beams/slabs, by intermittent fillet welding. Steel surfaces shall be provided with 2 coats of red oxide zinc chrome primer and 3 coats of synthetic enamel paint finish.

The Contractor shall construct recesses at all joints and on both faces of the concrete work except on the underside of ground slabs. The recesses shall be accurately formed to the lines and dimensions shown on the Drawings or as agreed with the Engineer. The Contractor shall prepare the surfaces of the recess and shall supply a joint sealer and fill or caulk the recess completely with it. Joint sealing shall not be commenced without the approval of the Engineer. In reservoir joints the sealer shall be poured after completion of the water tightness test, to the satisfaction of the Engineer. All joint sealers shall be from an approved manufacturer. The Contractor shall supply the manufacturer's test certificates for each consignment of each type of joint sealant delivered to the Site and shall if requested supply to the Engineer sufficient samples of each type and consignment for confirmatory tests to be carried out in accordance with the appropriate test procedure. Sealants shall be installed in strict accordance with the manufacturer's instructions. De-bonding strip shall be used in conjunction with the sealers as indicated on the Drawings. The de-bonding strip shall be compatible with the joint sealer and shall be resistant to attach from the primer used to bond the sealer to the concrete. Polysulphide and polyurethane sealants shall not abut bitumen sealers. Surfaces to receive Polysulphide and polyurethane sealants shall be kept free from bituminous paints. All sealants shall be appropriate for the prevailing climatic conditions. Bituminous sealants shall comply with the BS 2499 for Type A1. Polysulphide sealants shall comply with IS 12118.

5A.4.32. Concreting Records

A written record of the concrete works shall be made each day by the Contractor and kept available for inspection by the Engineer. The diary shall contain notes and records of :

1. The names of the Contractor's Engineer who are responsible for the different phases of the concrete work and also the names of their assistants.

2. The temperatures of air, water, cement, aggregates, together with the air humidity and type of weather.

3. Deliveries to the Site of concrete materials (quantity, brand of concrete, etc).

4. Inspections carried out, tests performed, etc. and their results.

5. Times of commencement and completion of different parts of the concrete works and times of erection and striking of forms.

6. Quantity of cement, fine and coarse aggregate and admixture used for each section of work and the number and kind of test samples taken on these ingredients and water.

Concrete Pour Card

Client :	Date : Pour No. :
Project :	Structure :
Contractor :	Max. Aggregate Size / Slump :
Drg. No. :	Start / Completion Time : /
Concrete Grade / Quantity : /	Mixing Time :

Sl. No.	Item			Contractor's Rep. Sign	Engineer's Sign	Remarks
1.	Before Concreting	Centrelines Checked				Pour Authorised Site Engineer
2.		Formwork And Staging Checked For Accuracy, Strength & Finish				
3.		Reinforcement Checked				
4.		Cover To Reinforcement Checked				
5.		Verified Test Certificate For Cement/Steel		Yes / No	Yes / No	
6.		Adequacy Of Materials / Equipment For Pour		Yes / No	Yes / No	
7.		Embedded Part S	Civil			
		Checked	Mechanical			
		(Location & Plumb)	Electrical			

8.	Soffit(S) & Pour Top(T) Levels Checked Before (B) & After (A) Form Removal (Only Of Beams Of Over 10 M Span & Important Structure Like T.G. Etc.)	S(B) T(B) S(A) T(A)	
9.	Construction Joints Location & Time (If Not As Per Drawing)		
10.	Cement Consumption In Kgs.		
11.	Number Of Cubes And Identification Marks		
12.	Test Cube Results (7 Days / 28 Days)		
13.	Concrete Condition On Form Removal	V.Good/Good/Fair/Poor	

Site-in-charge

Notes : 1. Each item to be checked and signed by the respective engineers .

2. Items 8 to 13 (both inclusive) to be filled only by engineer.

3. Each pour to have separate cards, in triplicate one each for client, consultant & site office.

Under remarks indicate deviations from dwgs. & specifications, congestion in reinforcement if any, unusual occurences, such as failure of equipments, sinking of supports / props. Heavy rains affecting concreting, poor compaction, improper curing, other deficiencies, observations etc.

Chapter – 5A.5

5A.5 - ROADS AND DRAINS

5A.5.1. Applicable Codes and Specifications

The following specifications, standards and codes are referred to in this part.

IS : 73 :	Specification for Paving Bitumen
IS : 215 :	Specification for Road Tar
IS : 217 :	Specification for Cutback Bitumen
IS : 454 :	Specification for Digboi type Cutback Bitumen
IS : 460 :	Specification for Test sieves
(Parts 1 to 3)	
IS : 1077 :	Common burnt clay building bricks - Specification
IS : 1124 :	Method of test for determination of water absorption, apparent specific gravity and porosity of building stones
IS : 1195 :	Specification for Bitumen Mastic for Flooring
IS : 1196 :	Code of Practice for Laying Bitumen Mastic Flooring
IS : 1834 :	Specification for Hot Applied Sealing Compounds for Joints in Concrete
IS : 2386 :	Methods of test for aggregates for concrete
(Parts 1 to 8)	
IS : 2720 :	Method of Test for Soils
(Part 5)	Determination of Liquid and plastic limit
IS : 6241 :	Method of test for determination of stripping value of road aggregates.
IRC : 15 :	Standard Specification and code of practice for construction of Concrete Roads (Third Revision)
IRC : 16 :	Specification for priming of Base Course with Bituminous Primers.
IRC : 17 :	Tentative specification for Single Coat Bituminous Surface Dressing
IRC : 19 :	Standard specifications and code of practice for water bound macadam
IRC : 37 :	Guideline for design of Flexible Pavements (Second Revision)
IRC : 29 :	Specification for bituminous concrete (Asphaltic Concrete) for road pavement

Ministry of Surface Transport : Specifications for road and bridge works (Roads wing)

All earthworks shall be according to Specifications specified elsewhere.

5A.5.2. Materials

5A.5.2.1 General

All materials shall be obtained from local sources and shall be subject to Engineer's approval prior to use.

5A.5.2.2 Soling Stone

It shall be clean, sound, dense, hard, tough, durable stone of uniform quality free from unsound material, cracks, decay and weathering. Water absorption shall not be more than 5 percent. The stone shall be in the smallest dimension equal to thickness of the soling course specified with a tolerance of 25 mm. Soling Stone shall be sufficiently flat bedded. The height of the soling stone shall be equal to the specified thickness of soling. The length and breadth shall not exceed twice the specified thickness.

5A.5.2.3 Stone Aggregate/Metal

Coarse aggregate, stone chippings shall consist of natural or crushed stone, clean, hard, tough, durable and free from excess of flat, elongated, soft and disintegrated particles, dirt, salt, alkali, vegetable matter, adherent coatings, organic and other objectionable matter, and shall conform to the physical requirements given in Tables 5.1 or 5.2 hereunder, as applicable. Aggregate for bituminous wearing courses shall in addition have good hydrophobic properties i.e. capacity of retaining the film of bituminous material applied to the stone in all weather conditions and especially in wet conditions. Basalt, dolerite are good in this respect; granite, quartzite are comparatively poor.

Table 5.1: Physical Requirements of Coarse Aggregate for Water Bound Macadam (Sub Base/ Base Course)

S. No	Test	Requirements	Test Method
1.	Los Angeles Abrasion Value* Or Aggregate Impact Value*	50 percent (max.) 40 percent (max.)	IS:2386 (Part – IV) IS:2386 (Part – IV) Or IS:5640***
2.	Flakiness Index **	15 percent (max.)	IS:2386 (Part I)

(*) Aggregate may satisfy requirements of either of two tests.

(**) Requirements of flakiness index shall be enforced only in case of crushed broken stone.

(***) Aggregates like brick, metal, kankar, laterite etc., which get softened in presence of water shall be tested for impact value under wet conditions in accordance with IS: 5640.

Table – 5.2 Physical Requirements of Aggregates for Bituminous Wearing Course

S. No.	Test	Requirements	Test Method
1.	Los Angeles Abrasion Value* Or	40 percent (max.)	IS:2386 (Part – IV)
	Aggregate Impact Value*	30 percent (max.)	IS:2386 (Part – IV)
2.	Flakiness Index **	35 percent (max.)	IS:2386 (Part I)
3.	Stripping Value	25 percent (max.)	IS:6241
4.	Water Absorption	2 percent (max.)	IS:2386 (Part-III)
5.	Soundness		
	Loss with Sodium Sulphate – 5 cycles	12 percent (max.)	IS:2386 (Part-V)
	Loss with Magnesium Sulphate – 5 cycles	18 percent (max.)	

(*) Aggregate may satisfy requirements of either of two tests

(**) Requirement of flakiness index shall be enforced only in case of crushed broken stone

The coarse aggregate for water bound Macadam shall conform to one of the gradings given in Table-5.3 below :

Table – 5.3 Grading Requirements of Coarse Aggregates For Water Bound Macadam

Grading No.	Size Range	Sieve Designation	Percent by Weight Passing the Sieve
1.	90mm to 45mm	125 mm 90 mm 63 mm 40 mm 22.4 mm	100 90-100 25-60 0-15 0-5
2.	63mm to 45mm	90 mm 63 mm 53 mm 45 mm 22.4 mm	100 90-100 25-75 0-15 0-5

3.	53mm to 22.4 mm	63 mm 53 mm 45 mm 22.4 mm 11.2 mm	100 95-100 65-90 0-10 0-5

5A.5.2.4 Screenings for Water Bound Macadam

Screenings to fill voids in the coarse aggregate shall consist of the same materials as the coarse aggregate. However, where permitted, predominantly non-plastic material such as murum or gravel (other than river borne material) may be used for this purpose provided liquid limit and plasticity index of such material is below 20 and 6 respectively and fraction passing 75 micron sieve does not exceed 10 percent.

Screenings shall conform to the gradings set forth in Table – 5.4. Screenings of Type-A in Table-5.4 shall be used with coarse aggregate of grading 1 in Table – 5.3. Screenings of Type A or B, as approved, shall be used with coarse aggregates of grading 2. Type-B screenings shall be used with coarse aggregates of grading 3.

Table –5.4 Gradings For Screenings

Grading No.	Size Range	Sieve Designation	Percent by Weight Passing the Sieve
A	12.5 mm	12.5 mm 10.0 mm 4.75 mm 150 micron	100 90-100 10-30 0-8
B	10 mm	10 mm 4.75 mm 150 micron	100 85-100 10-30

The use of screening shall be omitted in the case of soft aggregates such as brick metal, kankar, laterites etc. as they are likely to get crushed to a certain extent under rollers.

5A.5.2.5 Binding Material

Binding material shall comprise of a suitable material, approved by Engineer, have plasticity index value of less than 6 as determined in accordance with IS : 2720 (Part - V)

Application of binding material may not be necessary, when the screenings used are of crushable type such as murum or gravel.

5A.5.2.6 Murum/Kankar/Gravel/Sand

Murum shall contain low plasticity binder material mixed with hard granular particles such as sand and/or gravel. Murum shall be sound and hard of a quality not affected by weather, to be screened at the quarry and free from all impurities. Large lumps shall all be broken at the quarry and murum delivered at site must pass in every direction through a 63 mm ring. Murum shall not contain more than 5% to 8% of fines passing a 75 micron sieve.

Gravel shall be composed of large, coarse, silicious grains, sharp and gritty to the touch, thoroughly free from dirt, organic and deleterious matter. It shall be hard, tough, dense and shall not contain particles bigger than 12 mm and more than 10 percent silt.

Sand used for blinding the bituminous road surface, shall be coarse, sharp, gritty, clean, granular material. Only material passing through 4.75 mm sieve and retained on 75 micron sieve shall be used.

5A.5.2.7 Bituminous Materials

Bituminous materials shall conform to IS : 73, IS : 215, IS : 217 or IS : 454 as applicable and be of the grade specified.

5A.5.3. Earth work

5A.5.3.1 Earthwork in Excavation

In general the excavation shall be in accordance to Specifications specified elsewhere.

Profiles of road excavation shall be laid at 50 m intervals or as specified in Drawings to conform to the required alignment, sections, grades and side slopes and the lines of cuts shall be clearly marked.

Contractor shall on no account excavate beyond the slopes or below the specified grade unless so approved by the Engineer in writing. If excavation is done below the specified level or outside the section the Contractor shall be required to fill up with approved materials, in layers of 150 to 200 mm, watered and compacted as specified for the subgrade.The excavation shall be finished neatly, smoothly and evenly to the correct lines, grades, sections and side slopes as shown in the drawings or approved by Engineer.

5A.5.3.2 Earthwork in Embankment

The embankment shall be formed of earth obtained from approved source.

The ground over which embankment is to be formed shall be cleared of all brushwood, loose stones, vegetation, bushes, stumps, and all other objectionable matter and materials so removed shall be burnt off or disposed off as approved by Engineer.The cost of this clearing, burning and disposal shall be included in the unit rates quoted for embankment construction.

Profiles of embankment shall be set up with stout poles to mark the centre and edges of the formation with the top levels of formation clearly marked by paint or cut and the slopes with strings and pegs at every 10 metres on straight portions. Toe line may be marked with pick marks.

Before placing any embankment material the top 150 mm of soil strata receiving it shall be scarified and watered and compacted with one pass of 8 to 10T roller.

Embankment material shall be placed in successive horizontal layers of 200 mm depth extending to the full width of the embankment including the slopes at the level of the particular layer and 300 mm more on both sides to allow compaction of the full specified section. Before placing the next layer the surface of the underlayer shall be moistured and scarified with pick axes or spades to provide a satisfactory bond with the next layer. The extra loose stuff at the edges shall be trimmed later after completion of the bank work leaving the correct section fully compacted.

When boulders, broken stones and similar hard materials are mixed up with the embankment materials care shall be taken to see that they are distributed uniformly into the bank and that no hollows are left near them. No stone or hard material shall project above the top of any layer. Each layer of embankment shall be watered, levelled, and compacted as specified before the succeeding layer is placed. The surface of the embankment shall at all times during construction be maintained at such a cross fall as will shed water and prevent ponding. If the bank materials contains less than the optimum moisture, water shall be added to the loose layers of the embankment to bring the moisture uniformly upto requirement. If the material contains more than the required moisture it shall be allowed to dry until the moisture is reduced to the required extent. The moistured/dried loose layers shall be compacted with a power roller of 10 to 12 tonnes. The roller shall pass at least twice over the same area, once in the forward move and the second time in backward move. To allow for subsequent settlement the finished level of the embankment shall be kept higher than the specified level by one centimetre for every metre of the height of the bank.

Embankment shall be finished and dressed smooth and even to conform to the alignment, levels, cross sections, and dimensions shown on drawings with due allowance for shrinkage. Any damage caused by rain, or due to any other reason shall be made good in the finishing operation.

5A.5.4. Preparation of Subgrade

In general Earthwork in subgrade shall conform to Specifications specified elsewhere.

Immediately prior to the laying of the soling the subgrade shall be cleaned of all foreign substances, vegetation etc. Any ruts or soft yielding patches that appear shall be corrected and the subgrade dressed off parallel to the finished profile. The camber of subgrade shall conform in shape to that of the finished road surface. Camber boards shall be used to get the required section.

The prepared subgrade shall be lightly sprinkled with water, if necessary, and rolled with power roller of not less than 10 tonnes, till the soil is evenly compacted to 95% of Proctor density with 2%

variation in optimum moisture content. Roller shall pass minimum 5 runs on the subgrade. Rolling shall commence at the edges and progress towards the centre longitudinally. Each pass of the roller shall uniformly overlap not less than one third of the track made in the preceding pass. Any undulations in the surface that develop due to rolling shall be made good with approved earth and subgrade rerolled.

5A.5.5. Soling

Soling shall not be constructed on a wet subgrade.

Unless otherwise specified, the width of the soling shall be 230 mm more on either side than that of the waterbound macadam wearing course and the finished thickness of the soling course shall be 230 mm. The soling stones shall be laid with the largest face downwards and in contact with each other. The stones shall break joint as far as possible. The height of the soling stone shall be equal to specified thickness of soling.

As the laying of rubble advances the soling shall be hand packed by wedging and packing with 80 mm metal in the joints of the soling and driving them by hammers in place so as to fill the voids as completely as possible. This operation of hand packing shall closely follow the rubble laying. The soling shall be laid and hand packed true to grade and section and these shall be often checked by boning rods, template boards and fish line etc. The grades, sections etc. of the soling shall correspond to those of the surfacing coming on it. The soling thus laid shall be finished by knocking out projecting stones and filling depressions by chips to come up to the grade and camber.

The quality of the 80 mm metal shall be same as specified for the soling and the longest dimension shall not be more than 100 mm and the shortest dimension not less than 50 mm.

The soling after it is properly laid and hand packed including filling of voids with 80 mm metal shall be rolled dry with 10 - 12 T power roller to refusal i.e., till the stones in the soling course cease to move under the roller and no more compaction can be achieved. Rolling shall start at the edges and work towards the centre. The roller shall run over the same surface of rolling for at least 8 times till the soling course is well consolidated. The surface shall be checked by templates and in case of unevenness high spots shall be knocked out and depressions filled by spalls and recompacted fully. Bunds shall be laid along the edges and compacted before starting rolling on soling to prevent spreading of stones.

Gravel shall be spread in thin layers over the above prepared soling surface, swept into the interstices with brooms, watered lightly to assist the filling of voids. Spreading of gravel, sweeping and watering shall continue till the interstices are completely filled. At all times only enough water shall be sprinkled to force the gravel into the voids and never so much as to soften the subgrade. The process of gravel filling shall be accompanied by rolling as for dry rolling of soling with a power roller weighing not less than 10 tonnes starting at edge and working towards the centre. The roller shall run over the same surface for at least eight times. Each pass of the roller shall uniformly overlap not less than one third of the track made in the preceding pass. The surface shall be checked with templates of approved design (to be provided by Contractor) and high and low spots corrected by removing soling and repacking.

5A.5.6. Sub-base

5A.5.6.1 General

The sub-base shall not be constructed on a wet subgrade.

The width of the sub-base course shall be 150 mm more on either side than that of the waterbound macadam wearing course. The finished thickness of the sub-base course shall be 160 mm. The sub-base metal course shall be laid in 2 layers, each of thickness 120 mm and finished to 80 mm.

5A.5.6.2 Spreading and Rolling

The metal shall be spread uniformly and evenly upon the prepared base to a thickness of 120 mm. The spreading shall be done from stock piles along the side of the roadway. In no case shall be the aggregates be dumped in heaps directly on the surface prepared to receive the metal nor shall hauling over uncompacted or partially compacted base be permitted. The surface of the aggregate shall be carefully checked, with templates and all high or low spots remedied by removing or adding aggregate as may be required. No segregation of large or fine particles shall be allowed and the coarse aggregates as spread shall be of uniform gradations with no pockets of fine material.

Immediately following the spreading of the metal rolling shall be started with wheeled power rollers of 10 to 12 tonnes capacity or tandem or vibratory rollers of approved type. Rolling shall begin from the edges gradually progressing towards the centre. First the edge(s) shall be firmly compacted with roller running forward and backward. The roller shall then move inwards parallel to the centreline of the road, in successive passes uniformly lapping preceding tracks by at least one half width.

Rolling shall be continued until the road metal has been thoroughly keyed and forward movement of stones ahead of the roller is no longer visible. Slight sprinkling of water may be done if necessary.

5A.5.6.3 Application of Screening

After the metal has been thoroughly keyed and set by rolling, screening to completely fill the interstices shall be applied gradually over the surface. These shall not be damp or wet at the time of application. Dry rolling shall be done while the screening is being spread so that vibrations of the roller cause them to settle in the voids. The screenings shall not be dumped in piles but be spread uniformly by spreading motion of hand shovels.

The dry rolling now shall be accompanied by brooming with hand brooms, wire brushes or both. In no case shall the screenings be applied so fast and thick as to form cakes or ridges on the surface in such a manner as would prevent, filling of voids or prevent the direct bearing of the roller on the metal. These operations shall continue until no more screenings can be forced into the voids in the metal.

5A.5.6.4 Sprinkling and Grouting

Now the surface shall be copiously sprinkled with water, swept and rolled. Hand brooms shall be used to sweep the screening into voids and to distribute them evenly. The sprinkling, sweeping and rolling operations shall be continued with additional screenings applied as necessary, until the coarse aggregate has become well bonded and firmly set in its full depth and a grout has been formed of the screenings. Care shall be taken to see that the underlying layers do not get damaged due to the addition of excessive quantities of water during construction. After the first layer of the sub-base has fully set, to the satisfaction of the engineer, the second layer shall be laid. The constructional operation for the second layer will be the same as that specified herein for the first.

5A.5.7. Waterbound Macadam Course

The surface over which water bound Macadam is to be laid shall be prepared to the specified grade and camber and made free of dust and other extraneous material. Any ruts or soft yielding places shall be corrected in an approved manner and rolled until firm. To prevent the spreading of the course aggregate during rolling, if necessary, two parallel mud walls 200 mm wide and of height equal to uncompacted Macadam course shall be made along the outer edges of the Macadam course having a clear distance between them equal to the width to be metalled.

W.B.M. sub-base course of specified thickness shall be provided. The course aggregate for this shall conform to requirements of sub-base in Table-5.1 and its grading shall conform to Grading 1 of Table - 5.3 and screening to Type B of Table-5.4.

W.B.M. base course : The coarse aggregate for this shall normally conform to requirements for Base in Table-1 and its grading shall confirm to Grading 3 of Table – 5.3 and screening to Type-B of Table-5.4.

5A.5.7.1 Preparation of Base

The base to receive the waterbound macadam course shall be prepared to the specified grade and camber and made free of dust and other extraneous material. Any ruts or soft yielding places shall be corrected in an approved manner and rolled until firm.

5A.5.7.2 Spreading Coarse Aggregate

The coarse aggregates conforming to the specifications shall be spread uniformly upon the prepared base to 110 mm which shall be compacted to 80 mm.

The spreading shall be done from stockpiles along the side of the roadway or directly from vehicles. In no case shall the aggregate be dumped in heaps directly on the surface prepared to receive the aggregate nor shall hauling over uncompacted or partially compacted base be permitted.

The surface of the aggregates spread shall be carefully checked with templates and all high or low spots remedied by removing or adding aggregate as may be required. No segregation of large or fine particles shall be allowed and the coarse aggregate as spread shall be of uniform gradation with no pockets of fine material.

The coarse aggregate shall not normally be spread over more than 3 days in advance of the subsequent construction operations.

5A.5.7.3 Rolling

Immediately following the spreading of the coarse aggregate, rolling shall be started with three wheeled power rollers of 10 to 12 tonne capacity or tandem or vibratory rollers of approved types. The weight of the roller shall depend upon the type of aggregate and shall be indicated by the Engineer.

Except on superelevated portions where the rolling shall proceed from inner edge to the outer, rolling shall begin from the edges gradually progressing towards the centre. First the edge(s) shall be compacted with roller running forward and backward. The roller shall then move inwards parallel to the centre line of the road, in successive passes uniformly lapping the preceding tracks by at least one half width.

Rolling shall be discontinued when the aggregates are partially compacted with sufficient void space in them to permit application of blindage. During rolling slight sprinkling of water may be done if necessary. Rolling shall not be done when the subgrade is soft or yielding or when it causes a wave-like motion in the subgrade or base course.

The rolled surface shall be checked transversely and longitudinally with templates and any irregularities corrected by loosening the surface, adding or removing necessary amounts of aggregate and re-rolling until the entire surface conforms to the desired camber and grade. In no case shall the use of blindage be permitted to make up depressions.

5A.5.7.4 Application of Screening

After the coarse aggregate has been rolled in accordance with Clause 5.8.3, screenings to completely fill the interstices shall be applied gradually over the surface. These shall not be damp or wet at the time of application. Dry rolling shall be done while the screenings are being spread so that vibrations of the roller cause them to settle into the voids of the coarse aggregate. The screenings shall not be dumped in piles but be spread uniformly in successive thin layers. Screenings shall be applied at a slow and uniform rate (in three or more applications) so as to ensure filling of all the voids. This shall be accompanied by dry rolling and brooming with mechanical brooms, hand brooms or both. In no case shall screenings be applied so fast and thick as to form cakes and ridges on the surface in such a manner as would prevent filling of voids or prevent the direct bearing of the roller on the coarse aggregate. These operations shall continue until no more screenings can be forced into the voids of the coarse aggregate. Spreading, rolling and brooming of screenings shall be carried out in only such lengths of the road which could be completed within one day's operation.

5A.5.7.5 Application of Blindage

After the coarse aggregate has been rolled, blindage conforming to specifications to completely fill the interstices shall be gradually applied over the surface. These shall not be damp or wet at the time of application. Dry rolling shall be done while the blindage is being spread so that vibrations of the roller

cause them to settle into the voids of the coarse aggregate. The blindage shall not be dumped in piles but be spread uniformly in successive thin layers either by the spreading motion of hand shovels or by mechanical spreaders or directly from trucks. Trucks operating for spreading the blindage shall be so driven as not so disturb the coarse aggregate.

The blindage shall be applied at a slow and uniform rate (in three or more applications) so as to ensure filling of all voids. The rate of spreading blindage shall not be less than 3.00 cu.m or more than 4.50 cu. m per 100 sq.m. This shall be accompanied by dry rolling and brooming with mechanical brooms, hand brooms or both. In no case shall the blindage be applied so fast and thick as to form cakes or ridges on the surface in such a manner as would prevent filling of voids or prevent the direct bearing of the roller on the coarse aggregate. The operations shall continue until no more blindage can be forced into the voids of the coarse aggregate.

The spreading, rolling and brooming of blindage shall be carried out in only such lengths of the road which could be completed within one day's operation.

5A.5.7.6 Application of Binding Material

After the application of screenings in accordance with Clauses 5.8.4 and 5.8.5, the binding material where it is required to be used (See Clause 5.3.5) shall be applied successively in two or more thin layers at a slow and uniform rate. After each application, the surface shall be copiously sprinkled with water, the resulting slurry swept in with hand brooms or mechanical brooms to fill the voids properly and rolled, during which water shall be applied to the wheels of the rollers, if necessary, to wash down the binding material sticking to them. These operations shall continue until the resulting slurry after filling of voids, forms a wave ahead of the wheels of the moving roller.

5A.5.7.7 Sprinkling and Grouting

After the blindage have been applied, the surface shall be copiously sprinkled with water, swept and rolled. Hand brooms shall be used to sweep the wet blindage into voids and to distribute them evenly. The sprinkling, sweeping and rolling operations shall be continued with additional blindage applied as necessary until the coarse aggregate had been thoroughly keyed, well-bonded and firmly set in its full depth and a grout has been formed of blindage. Care shall be taken to see that the base or subgrade does not get damaged due to the addition of excessive quantities of water during construction.

5A.5.8. Setting and Drying

After the final compaction of water bound macadam course, the road shall be allowed to dry overnight. Next morning hungry spots shall be filled with blindage as directed, lightly sprinkled with water, if necessary and rolled. No traffic shall be allowed on the road until the macadam has set. The Engineer shall have the discretion to stop hauling traffic from using the completed water bound macadam course if in his opinion it would cause damage to the surface.

Should the subgrade at any time become soft or churned up with the sub-base metal, or the water bound macadam course, the Contractor shall without additional compensation remove the mixture from the affected portion, reshape and compact the subgrade and replace the removed section in accordance with the foregoing requirements.

5A.5.8.1 Multiple Layered Course

When the total consolidated thickness of the water bound Macadam course is more than 100 mm, it shall be constructed in layers. Each layer shall be constructed as per all the operations described above. The same degree of quality control and refinement shall be used for constructing each layer.

5A.5.9. Semi-Grout

5A.5.9.1 Brushing

Prior to spreading of 25 mm and 40 mm metal for asphalt surface, the water bound surface shall be swept clean to remove all Blindage so as to expose the metal surface.

5A.5.9.2 Semi Grout Surface 80 mm thick

After the surface is cleaned as above and after removing all loose and foreign matter, the coarse aggregate shall be spread upon the base in a uniform loose layer. The size of metal shall be 25 mm and 40 mm. Every precaution shall be taken to prevent the aggregate from mixing or being coated with dust or any other objectionable matter, before and after spreading.

The coarse aggregate shall then be dry rolled with a road roller weighing not less than 10 tonnes. The rolling shall start longitudinally at the sides and proceed towards the centre of the pavement, overlapping on successive trips by at least one half of the width of the roller. The compacted coarse aggregate shall possess a fairly firm even surface, true to the grades and cross sections shown on the drawings and present a texture which will allow uniform penetration of the asphalt. If any irregularities appear during or after rolling, they shall be remedied by loosening the surface and removing or adding coarse aggregate as may be required, after which the area disturbed, including the sounding surface shall be rolled, until satisfactorily compacted to a uniform surface. All coarse aggregate which becomes coated or mixed with dirt, dust or foreign substance, prior to the application of asphalt shall be removed and replaced by clean aggregate of the same kind and compacted as specified.

5A.5.9.3 First Application of Bitumen

Upon the rolled coarse aggregate, bitumen of grade S35 or S65 heated to a temperature of 204 ^{0}C (400^{0}F) and quality as specified shall be uniformly applied at the rate of 5.5 kg/m^2 using gravel or coarse sand to reduce the interstices between the metal before application if it is found that the quantity of bitumen specified is insufficient to fill the interstices satisfactorily. Bitumen shall be applied only when the course is thoroughly dry for its entire depth, and passed by the engineer. Bitumen shall be applied hot by means of a pressure distributor as described below :

The pressure distributors used for applying bitumen shall be equipped with pneumatic tyres and shall be so designed and operated as to distribute the bitumen in a uniform spray without atomization in the amount and between the limits of temperature, specified. It shall be equipped with a fifty wheel speed tachometer registering feet per minute and so located as to be visible to the truck driver to enable him to maintain the constant speed required for application at the specified rate. The pump shall be operated by a separate power unit or by the truck power unit. It shall be equipped with a tachometer registering gallons per minute passing through nozzles and readily visible to the operator. Suitable means for accurately indicating at all times the temperature of the bitumen shall be provided. The thermometer shall be so placed as not to be in contact with the heating tube. The distributor shall be so designed that the normal width of application shall not be less than 2 m. with provision for the application of lesser width when necessary. If provided with heating attachments, the distributor shall be so equipped and operated that the bitumen shall be circulated or agitated throughout the entire heating process.

5A.5.9.4 Filling surface voids with intermediate aggregate

After the first application of asphalt and while still warm, a thin layer of dry intermediate aggregate consisting of 12.5 mm metal chips conforming to the specifications for physical requirements and grading shall be casted over the treated surface at a rate of 2.1 cubic metres per 100 square metres or in such quantity as to fill the surface voids and just cover the first coat. It shall be broomed if necessary to break up all heaps and produce a uniform covering, after which the pavement shall be rolled until thoroughly compacted and interlocked.

Suitable precautions shall be taken to prevent the distribution of intermediate aggregate over portion of the coarse aggregate which has not received the application of asphalt and in no case shall be dumped directly upon either the treated or untreated coarse aggregate.

5A.5.9.5 Protection of Semi Grout

During the period, between the initial compaction of the coarse aggregate and completion of the seal coat, the surface shall be protected from all traffic other than absolutely essential.

5A.5.10. Premixed Asphaltic Carpet

This work shall consist of constructing in a single course of 50 mm thick Premixed Asphaltic Carpet to the following Employer's Requirements on a previously prepared base, to serve as a wearing coat.

5A.5.10.1 Materials

Binder

This shall be paving bitumen of penetration grade within the range S 35 to S 90 or A 35 to A 90 (30-40 to 80/100) as per Indian Standard for `Paving Bitumen' IS: 73. The actual grade of bitumen to be used shall be decided by the Employer's Representative appropriate to the region, traffic, rainfall and other environmental conditions.

Coarse Aggregate

It shall be crushed material retained on 2.36 mm (No. 8 ASTM) sieve and shall be crushed stone or gravel (shingle) and shall be as per Clause 5.3.3 and satisfy the physical requirements set forth in Table-5.2.

Fine Aggregates

The fine aggregates shall be the fraction passing 2.8 mm sieve and retained on 90 micron sieve consisting of crusher run screenings, natural sand or mixture of both. These shall be clean, hard, durable, uncoated, dry and free form any injurious, soft or flaky pieces and organic or deleterious substances.

Filler

The filler shall be an inert material, the whole of which passing 710 micron, sieve, at least 90 percent passing 180 micron sieve and not less than 70 percent passing 90 micron sieve. The filler shall be stone dust, cement, hydrated lime, fly ash or any other non-plastic mineral matter approved by the Employer's Representative.

5A.5.10.2 Mineral Aggregate Gradation

The mineral aggregates including mineral filler shall be so graded or combined as to confirm to the either of the limits set forth in Table-5.5 below :

Table –5.5 Mineral Aggregate Gradation for Bituminous Concrete

Sieve Size	**Percent by Weight Passing the Sieve**	
	GRADING - 1	**GRADING - 2**
20mm	---	-100
12.5 mm	-100	80-100
10 mm	80-100	70-90
4.75 mm (No.4 ASTM)	55-75	50-70
2.36 mm (No.8 ASTM)	35-50	35-50
600 micorn (No.30 ASTM)	18-29	18-29
300 micron (No.50 ASTM)	13-23	13-23
150 micron (No.100 ASTM)	8-16	8-16

75 micron (No.200 ASTM)	4-10	4-10

5A.5.10.3 Mix Design

Apart from conformity with the grading and quality requirements of individual ingredients, the asphaltic concrete mix shall meet the requirements set forth in Table-5.6 hereunder

5A.5.10.4 Weather and Seasonal Limitations

Asphalt concrete shall not be laid during rainy weather or when the base course is damp or wet.

Table – 5.6 Requirement of Asphaltic Concrete Mix

S. No.	Description	Requirements
1.	Number of compaction blows, each end of Marshalling specimen	50
2.	Marshall stability (ASTM Designation-D-1559) determined on Marshal specimen	340 Kg. (min.)
3.	Marshall flow (mm)	2-4
4.	Percent Voids in mix	3-5
5.	Percent voids in mineral aggregate filled with bitumen	75-85
6.	Binder content percent by weight of mix	5-7.5

The contractor shall intimate to the Employer's Representative in writing, well in advance of the start of work, the job- mix formula proposed to be used by him for the work and shall give following details to the Employer's Representative for his approval.

i) Source and location of all materials

ii) Proportions of all materials expressed as follows where each is applicable :

Binder	As percentage by weight of total mix
Course aggregate	As percentage by weight of total aggregate including mineral filler
Fine aggregate	
Mineral filler	

iii) A single definite percentage passing each sieve for the mixed aggregate.

iv) The results of the best enumerated in Table-5.6 as obtained by the Contractor.

v) Test results of physical characteristics of aggregates to be used.

Should a change in the source of material be proposed, a new job mix formula shall be established and got approved from the Employer's Representative before actual using the materials.

5A.5.10.5 Preparation of Base

The base on which premix carpet is to be laid shall be prepared, shaped and conditioned to the specified lines, grade and cross section by repairing all potholes or patches and ruts. The potholes shall be drained of water and cut to regular shape with vertical sides. All loose and disintegrated material shall be removed. The pothole shall then be filled either with (i) Coarse aggregate and screenings conforming to Clause 5.3.0 and compacted with heavy hand rammers or approved mechanical tempers or (ii) premixed chippings binders (bitumen grade 80/100) content of 3 percent by weight of total mix, after painting the sides and bottom of the holes with a thin application of bitumen, or a combination of both (i), (ii) as approved by Employer/Employer's Representative. The surface shall be thoroughly swept and scraped clean and free of dust and other foreign matter.

5A.5.10.6 Tack Coat

The binder used for tack coat shall be bitumen of suitable penetration grade within 80/100 confirming to IS:73. The actual grade of bitumen to be used shall be decided by the Employer's Representative, appropriate to the region, traffic, rainfall and other environmental conditions. Binder shall be heated to the temperature appropriate to its grade and as approved by the Employer's Representative. The binder shall be sprayed on the prepared base at the rate of 1.0 kg/sq.m. The binder shall applied uniformly with the aid of either self propelled or towed bitumen pressure sprayer with self heating arrangement and spraying nozzle arrangement capable of spraying bitumen at the above specified rate and temperature so as to provide uniform unbroken spread of bitumen. The tack coat shall be applied just ahead of oncoming premixed asphalt carpet.

5A.5.10.7 Preparation of Mix and Laying

Hot mix plant of adequate capacity and capable of producing a proper and uniform quality mix shall be used for preparing the mix. The plant may be either a weigh batch type or volumetric proportioning continuous or drum mix type. The stone aggregate shall be surface dry and contain not more than 2 percent moisture before use. It shall be first screened of dust and measured in boxes, heated to 155 deg.C - 163 deg. C and then loaded into the drum mixer according to the capacity of the mixing drum in the proportion specified. The binder shall be heated to 140 deg. C to 177 deg. C in boilers and maintained at that temperature. At no time shall the difference in temperature between the aggregate and binder exceed 14 deg. C. The heated binder shall be drawn from the boiler into a suitable container or in a bucket gauged to show the weight of bitumen in it.

Mixing shall be done in two stages. The coarse aggregate of the correct standard size and in the proportion as specified shall be fed into the mixer to which 2/3rd of the total specified quantity of bitumen heated to the appropriate temperature shall be added. When the coarse aggregate is well coated, the fine aggregate in the specified proportion followed by the balance 1/3rd quantity of total bitumen shall be fed into the mixer. Mixing shall be continued until a homogeneous mix is produced and all particles are uniformly coated with bitumen.

The hot mix shall be discharged from the mixer carried to the point of use in suitable tipper vehicles and shall be spread by means of a self propelled mechanical paver with a suitable screeds capable of spreading, tamping and finishing the mix to specified lines and levels to a thickness sufficient to achieve after consolidation the specified thickness. Temperature of the mix at the time of laying shall be in the range of 120 deg. C - 160 deg. C. However, in restricted locations and in narrow width where available equipment can not be operated in the opinion of the Employer’s Representative, he may permit manual laying of the mix. Longitudinal joints and edges shall be constructed true to the delineating lines parallel to the centre line of the road. Longitudinal joints shall be offset by at least 150 mm from those in the binder course (tack coat). All joints shall be cut vertical to the full thickness of the previously laid mix and the surface painted with hot bitumen before placing fresh material.

5A.5.10.8 Rolling

Immediately after the spreading of mix it shall be thoroughly compacted by rolling with a set of rollers moving at a speed not more than 5 km per hour. The initial or break down rolling shall be with 8-12 ton three wheel roller and the surface finished by final rolling with the 8-10 ton tendem roller. Preferably before finishing with tendem, breakdown rolling shall be followed by an intermediate rolling with a fixed wheel pneumatic roller of 15 to 30 ton having a tyre pressure of 7 kg. per sq.m. The joints and edges shall be rolled with a 8 to 12 ton three wheel roller. Any high spots or depressions which become apparent shall be corrected by addition of removal of mix material. The roller shall uniformly overlap not less than a third of the track made in the preceding pass. The wheels of the roller shall be moistened with gunny bags to prevent the mix sticking to the wheels while rolling, but in no case shall fuel lubricating oil be used for this purpose. Rolling shall be continued till the mix is thoroughly compacted and all roller marks are eliminated.

5A.5.10.9 Opening to Traffic

Traffic shall be allowed on the road after a lapse of minimum 24 hours, preferably 48 hours after laying as approved by the Employer’s Representative.

5A.5.11. Seal Coat

This work shall consist of application of a seal coat sealing the voids in a bituminous surface laid to the specified levels, grade and camber. Seal coat shall be either of the two types below

Type A : Liquid seal coat comprising of an application of a layer of bituminous binder followed by a cover of stone chippings.

Type B : Premixed seal coat comprising of a thin application of fine aggregate premixed with bituminous binder.

5A.5.11.1 Materials

Binder

This shall be 30/40, 60/70 or 80/100 grade straight run bitumen conforming to IS:73. The actual grade of bitumen to be used shall be approved by the Engineer, appropriate to the region, traffic, rainfall and other environmental conditions. The quantity of binder to be utilized, shall be 9.8 kg and 6.8 kg per 10 sq.m. of area for Type A and Type B seal coat respectively.

Stone Chippings for Type A Seal Coat

These shall consist of angular fragments of clean, hard, tough and durable rock of uniform quality throughout. They should be free of elongated or flaky pieces, soft or disintegrated stone, vegetable or other deleterious matter. Stone chippings shall be of 10 mm size defined as 100 percent passing through 12.5 mm sieve and retained on 2.36 mm sieve. The quantity used for spreading shall be 0.09 cum per 10 sq.m.

Fine Aggregate for Type B Seal Coat

The fine aggregate shall be sand or fine grit and shall consist of clean, hard, durable, uncoated dry particles and shall be free from dust, soft or flaky material organic matter or other deleterious substances. The aggregate shall pass 1.7 mm sieve and be retained on 180 micron sieve. The quantity used for premixing shall be 0.06 cu.m. per 10 square metre area.

5A.5.11.2 Preparation of Base

The seal coat shall be applied immediately after the laying of bituminous course which is required to be sealed. Before application of seal coat materials the surface shall be cleaned free of any dust or other extraneous matter.

5A.5.11.3 Construction of Type A Seal Coat

Application of Binder

Binder shall be heated in boilers to 163 deg. C to 171 deg. C, maintained at the temperature and sprayed on the dry surface in a uniform manner with the help of mechanical sprayers. Excessive deposits of binder caused by stopping or starting of the sprayer through leakage or any other reason shall be suitably corrected before the stone chippings are spread.

Application of Stone Chipping

Immediately after the application of the binder, stone chippings in a dry and clean state shall be spread uniformly on the complete surface. If necessary the surface shall be broomed to ensure uniform spread of chippings. The surface shall be checked by means of a camber board laid across the road and a 3 metre straight edge laid parallel to the centre line of the road and undulations if any, shall be corrected by addition or removal of blindage.

Rolling

Immediately after the application of the material, the entire surface shall be rolled with a 8 to 10 tonne smooth wheeled roller. While rolling is in progress additional material shall be spread by hand in whatever quantities required to make up irregularities. Rolling shall continue until all material is firmly bedded in the binder and presents a uniform closed surface. Generally five to six passes shall be made for thorough compaction of the surface or as approved by the Engineer. Along kerbs, manholes and at all places not accessible to roller, thorough compaction shall be secured by means of steel rammers or hand rollers. Traffic shall be allowed after 24 hours. After a period of seven days, surplus grit shall be swept and collected and shall be used for binding the spots where bleeding occurs.

5A.5.11.4 Construction of Type B Seal Coat

Preparation of Mix and Laying

The aggregate shall be surface dry and contain not more than 2 percent moisture before use, and shall be heated to 155 deg. C to 163 deg. C and then loaded into the drum mixer according to the capacity of the mixing drum in the proportion specified. The binder shall be heated to 149 deg. C to 177 deg. C in boilers and maintained at that temperature. At no time shall the difference in temperature between the aggregate and binder exceed 14 deg. C. The heated binder shall be drawn from the boiler into a suitable container or in a bucket gauged to show the weight of bitumen in it. The mix shall be immediately transported from the mixing plant to the point of use and spread uniformly on the bituminous surface to be sealed.

Rolling

As soon as sufficient length has been covered with the premixed material, the surface shall be rolled with 8 to 10 tonne smooth wheeled power rollers. Rolling shall be continued till the premixed material completely seals the voids in bituminous course and a smooth uniform surface is obtained.

Opening to traffic

Traffic may be allowed soon after final rolling when, the premixed material has cooled down to the surrounding temperature.

5A.5.12. Quality Control

5A.5.12.1 General

All materials incorporated and all works performed shall be strictly in conformity with the Specification requirements. All works shall conform to the lines, grades, cross sections and dimensions shown on the drawings or as approved by the Engineer subject to the permitted tolerances described hereinafter. The Contractor shall be fully responsible for the quality of the work in the entire construction within the Contract. He shall, therefore, have his own independent and adequate set-up for ensuring the same.

The Contractor shall carry out quality control tests on the materials and work to the frequency specified. In the absence of clear indications about method and/or frequency of tests for any item, the approval of the Engineer shall be obtained and he shall provide necessary co-operation and assistance in obtaining the samples for test and carrying out the field test as required by the Engineer from time to time. This may include provision of Labour, attendance, assistance in packing and despatching and any other assistance considered necessary in connection with the test.

For the work of embankment, subgrade and construction of subsequent layer of same or other material over the finished layer shall be done after obtaining approval from the Engineer. Similar approval from the Engineer shall be obtained in respect of all other items of works prior to proceeding with the next stage of construction.

The Contractor shall carry out modification in the procedure of work, if found necessary, as approved by the Engineer during inspection. Works falling short of quality shall be rectified by the Contractor as approved by the Engineer.

The Contract rate quoted for various items of works in the Bill of Quantities or the lumpsum amount tendered shall be deemed to be inclusive of all costs of the quality control tests and operations necessary for ensuring quality of the material and work so as to be in conformity with the specification requirement.

5A.5.12.2 Permitted Tolerances

Horizontal Alignments

Horizontal alignments shall be reckoned with respect to the centre line of the carriageway as shown on the drawings. The edges of the carriageway as constructed shall be correct within a tolerance of ±25 mm therefrom. The corresponding tolerance for edges of the roadway and lower layers of pavement shall be ±40 mm.

Longitudinal Profile

The levels of the subgrade and different pavement courses as constructed, shall not vary from those calculated with reference to the longitudinal and cross- profile of the road shown on the drawings or as approved by the Engineer beyond the tolerances mentioned below :

Subgrade	± 15 mm
Sub-base	± 20 mm
Base Course	± 15 mm
Wearing Course	± 10 mm

Provided, however, that the negative tolerance for wearing course shall not be permitted in conjunction with the positive tolerance for base course if the thickness of the former is thereby reduced by more than 6 mm.

Surface Regularity

The surface regularity of completed subgrade, sub-bases, base courses and wearing surfaces in the longitudinal and transverse directions shall be within the tolerances indicated in Table 5.7.

The longitudinal profile shall be checked with a 3 metre long straight edge, at the middle of each traffic lane along a line parallel to the centre line of the road. The transverse profile shall be checked with a set of three camber boards at intervals of 10 metres.

Rectification

Where the surface irregularity of subgrade and the various courses fall outside the specified tolerances, the Contractor shall be liable to rectify these in the manner described below and to the satisfaction of the Engineer.

(i) Subgrade

Where the surface is high, it shall be trimmed and suitably compacted. Where the same is low, the deficiency shall be corrected by adding fresh material. The degree of compaction and the type of material to be used shall conform to the Clauses 5.3 and 5.4.

(ii) Water Bound Macadam

Where the surface is high or low, the top 75 mm shall be scarified, reshaped with added material as necessary and recompacted. The area treated at a place shall not be less than 5 metres long and 2 metres wide.

(iii) Bituminous Constructions

For bituminous construction other than wearing course, where the surface is low, the deficiency shall be corrected by adding fresh material and recompacting to Specifications. Where the surface is high, the full depth of the layer shall be removed and replaced with fresh material and compacted to Specifications.

For wearing course, where the surface is high or low, the full depth of the layer shall be removed and replaced with fresh material and compacted to Specifications. In all cases where the removal and replacement of a bituminous layer is involved, the area treated shall not be less than 5 metre long and not less than 1 lane wide.

Table 5.7 Permitted Tolerance of Surface Regularity for Subgrade and Pavement Courses

S. No.	Type of Construction	**Longitudinal profile with 3 Cross profile metre straight edge**					
		Maximum permissible undulation mm	Maximum number of undulations permitted in any 300 metres length exceeding : mm				Maximum permissible variation from specified profile under camber template : mm
			18	12	10	6	
1	2	3	4	5	6	7	8
1.	Earthen subgrade	24	30	-	-	-	15
2.	Granular/Lime/Cement/stabilised subbase	15	-	30	-	-	12
3.	Water Bound Macadam with over size metal (45-90 mm size)	15	-	30	-	-	12
4.	Water Bound Macadam with normal size metal (22-4-53 mm and 45-63 mm size)	12	-	-	30	-	8
5.	Bituminous concrete	8	-	-	-	10@@	4

Notes :

1. @@ These are for machine laid surfaces. If laid manually due to unavoidable reasons, tolerance upto 50 percent above these values in this column may be permitted at the discretion of the Engineer. However, this relaxation does not apply to the values of maximum undulation for longitudinal and cross profiles mentioned in columns 3 and 8 on the table.

2. Surface evenness requirements in respect of both the longitudinal and cross profiles should be simultaneously satisfied.

5A.5.13. Tests

5A.5.13.1 General

For ensuring the requisite quality of construction, the materials and works shall be subjected to quality control tests, as described hereinafter. The testing frequencies set forth are the desirable minimum and the Engineer shall have the full authority to increase the frequencies of tests as he may deem necessary to satisfy himself that the materials and works comply with the appropriate Specifications.

Test procedures for the various quality control tests are indicated in the respective Sections of these Specifications or for certain tests within this Section. Where no specific testing procedure is mentioned, the tests shall be carried out as per the prevalent accepted engineering practice to the approval of the Engineer.

Tests on Earthwork for Embankment and Subgrade Construction

Borrow material

(i) Sand content [IS:2720(Part IV)]

1-2 tests per 8000 cu. metres of soil

(ii) Plasticity Test [IS:2720(Part V)]

Each type to be tested , 1-2 tests per 8000 cu. metres of soil.

(iii) Density Test [[IS:2720(Part VII)].

Each soil type to be tested, 1-2 tests per 8000 cubic metres of soil.

(iv) Deleterious Content Test [IS:2720(PartXXVII)]

As and when required by the Engineer.

(v) Moisture Content Test [IS:2720(Part II)]

One test for every 250 cubic metres of soil.

(vi) CBR Test on materials to be incorporated in the subgrade on soaked/unsoaked samples [[IS:2720(part XVI)]

One test for every 3000 m^3 at least or closer as and when required by the Engineer.

Compaction control : Control shall be exercised by taking at least one measurement of density for each 1000 square metres of compacted area, or closer as required to yield the minimum number of test results for evaluation a days work on statistical basis. The determination of density shall be in accordance with IS:2720 (part XXVIII). Tests locations shall be chosen only through random sampling techniques. Control shall not be based on the result of any one test but on the mean value of a set of 5-10 density determinations. The number of tests in one set of measurements shall be 5 as long as it is felt that sufficient control over borrow material and the method of compaction is being exercised. If considerable variations are observed between individual density results, the minimum number of tests in one set of measurement shall be increased to 10. The acceptance of work shall be subject to the condition that the mean dry density equals or exceeds the specified density and the standard deviation for any set of results is below 0.08 gm/cc.

However, for earthwork in shoulders (earthern) and in top 500 mm portion of the embankment below the subgrade, at least one density measurement shall be taken for every 50 square metres of the compacted area provided further `that the number of tests in each set of measurements shall be at least 10. In other respects, the control shall be similar to that described earlier.

5A.5.13.2 Tests on Sub-bases and Bases (Excluding bitumen bound bases)

The tests and their frequencies for the different types of bases and sub-base shall be as given in Table 5.8. The evaluation of density results for compaction control shall be on lines similar to those set out in clause 5.10.1.

Table –5.8 Control Tests and Their Frequencies for Sub-Bases and Bases (Excluding Bitumen Bound Bases)

S. No.	Types of Construction	Test	Frequency
1.	Granular sub-base	i) Gradation ii) Atterbergs limit iii) Moisture content prior to compaction iv) Density of compacted layer v) Deleterious constituents vi) C.B.R	One test per 200 m^3 One test per 200 m^3 One test per 250 m^2 One test per 500 m^2 As required As required
2.	Lime/Cement Stabilised	i) Purity of lime (for lime-soil stabilization ii) Lime/Cement content iii) Degree of pulverisation iv) CBR test on a set of 3 specimens v) Moisture content prior to compaction vi) Density of compacted layer vii) Deleterious constituents	One test for each consignment subject to a minimum of one test per 5 tonnes of lime. **Regularly, through procedural checks.** Periodically as considered necessary. As required One test per 250 m^3. One test per 500 m^2 As required
3	Water Bound Macadam	i) Aggregate Impact Value ii) Grading iii) Flakiness Index iv) Atterbergs limits of binding	One test per 200m^3 of aggregate One test per 100 m^3 of aggregate One test per 200 m^3 of aggregate One test per 25 m^3 of binding material

S. No.	Types of Construction	Test	Frequency
		material.	

5A.5.13.3 Tests on Bituminous Constructions

The tests and their frequencies for the different types of bituminous works shall be as given in Table 5.9 hereunder.

Table – 5.9 Control Tests and Their Frequency for Bituminous Works

S. No	Types of Construction	Test	Frequency
1.	Prime Coat/Tack Coat	i) Quality of binder ii) Binder temperature for a application Rate of spread of binder	As Required At regular close intervals Two tests per day
2.	Seal Coat/Surface Dressing	i) Quality of binder ii) Aggregate Impact Value iii) Flakiness Index iv) Stripping value of aggregates v) Water absorption of aggregates vi) Grading of aggregates vii) Temperature of binder of application Rate of spread of materials	As required One test per 50 m^3 of aggregate One test per 50 m^3 of aggregate Initially, one set of 8 representative specimens for each source of supply. Subsequently when warranted by changes in the quality of aggregate One test per 25 m^3 of aggregate At regular close intervals One test per 500 m^3 of aggregate
3	Bituminous Concrete	i) Quality of binder ii) Aggregate impact value, flakiness index and stripping value of aggregates iii) Mix-grading iv) Control of	As required One test per 50-100m^3 of aggregate One set of test on individual constituents and mixed aggregates from the dryer for each 100 tonnes of mix subject to a maximum of two sets per plant per day. At regular close interval.

		temperature of binder in boiler, aggregate in the dryer and mix at the time of laying and rolling v) Stability of mix (vide ASTM:D-1559) vi) Binder content and gradation in the mix (Binder content test vide ASTM:D-2172) vii) Rate of spread of mixed material Density of compacted layer	For each 100 tonnes of mix produced, a set of three Marshall specimens to be prepared and tested for stability, flow value density, and void content, subject to a minimum of two sets being tested per plant per day. One test for each 100 tonnes of mix subject to a minimum of two tests per day per plant. Regular control through checks on the weight of mixed material and layer thickness. One test per 500 m^3 area

5A.5.14. Slab Culvert

Slab culverts shall be constructed at specified locations of the existing cross drainage works as per drawings, or as directed by the Engineer. The Concrete works specifications for construction of RC slab and the rubble masonry specifications for the supporting rubble walls are given in Section-4 and Section-8 respectively and they shall be followed.

5A.5.14.1 Bitumen at Location of Contact

The Bitumen to be used on the top of the bed concrete at the location of contact of RCC slab above in two coats, shall be straight run bitumen of specified grade.

5A.5.14.2 Graded Gravel Free Draining Backfill

On each side of the uncoursed rubble walls supporting the slab culvert a free draining backfill of thickness 200 mm shall be provided. The material for this backfill shall be granular consisting of sound, tough, durable particles of crushed or uncrushed gravel, crushed stone or brickbats which will not become powdery under loads and in contact with water. The material shall be free from soft, thin, elongated or laminated pieces and vegetable or other deleterious substances. It shall be graded and shall meet the grading requirements given in Table 5.10 hereunder.

Table 5.10

Sieve Designation	Percent Passing by Weight

10 mm	100
4.75 mm	30-65
425 microns	5-30
150 microns	0-10

5A.5.14.3 Weep Holes

Weep holes as shown on the drawings or as directed by the Engineer shall be provided in the masonry to drain water from the backfilling. Weep holes shall be of asbestos cement pipes conforming to IS 6908 in rubble walls with necessary M10 concrete cushioning, 75 mm thick. They shall extend through the full width of the masonry at a spacing of 1.5 m c/c and with slope of about 1 vertical to 20 horizontal (or as shown on the drawings) towards the draining face.

5A.5.15. Pipe Drains

Wherever required, pipe drains shall be provided for cross drainage purposes. The sequence of construction shall be as follows:

(a) laying of sand/shingle bedding on the original ground,

(b) laying of PCC of M10 grade,

(c) laying of concrete pipes of NP3 class as per IS 458,

(d) Constructing embankment above in compacted murum, laying of the sub-base and Waterbound Macadam as specified herein above.

The details of above works as directed by Engineer shall be followed.

5A.5.15.1 Materials for Pipe Drains

All materials used in the construction of pipe drains shall conform to the requirements of the Specifications. RCC pipes of NP3 class shall conform to IS 458.

Each consignment of cement concrete pipes shall be inspected, tested if necessary, and approved by Engineer at the place of manufacture or at site before their incorporation in the Works.

5A.5.15.2 Excavation for pipes

The foundation bed for pipe drain shall be executed true to the lines and grades shown on the drawings or as directed by the Engineer. The pipes shall be placed in shallow excavation of the natural ground in open trenches cut in the existing embankment, taken down to levels as shown in the drawings.

Where trenching is involved , its width on either side of pipe shall not be less than 150 mm nor more than one third the diameter of pipe. The sides of the trench shall be as nearly vertical as possible.

When during excavation, the material encountered is soft, spongy or other unstable soil, unless other special construction methods are called for as indicated on drawings, such unsuitable material shall be removed upto a depth of 600 mm or as directed by the Engineer. Before placing any backfill material, exposed surface of the soft soil shall be lightly compacted with one pass of 0.5 T roller. On the lightly compacted surface, coarse sand and shingle shall be spread in two successive layers of 300 mm and each layer shall be compacted by rolling with a min.0.5 T roller and with a minimum of 10 passes each, both in longitudinal and transverse directions.

When bed rock or boulder strata are encountered, excavation shall be taken down at least 300 mm below bottom level of pipe as directed by Engineer and space filled with approved sand and shingle and thoroughly compacted to provide adequate support for the pipes.

Trenches shall be kept free from water until the pipes are installed and the joints have been hardened . For this purpose, Contractor shall suggest necessary method for diverting the water.

5A.5.15.3 Bedding for pipe

The bedding surface shall provide a firm foundation of uniform density throughout the length of the pipe drain and shall conform to the specified level and grade.

The pipe shall be bedded in a cradle of concrete having a mix not leaner than M-10. The pipes shall be laid on the concrete bedding before the concrete has set.

5A.5.15.4 Laying of pipes

No pipe shall be placed in position until the foundations have been approved by Engineer. When pipes are to be laid adjacent to each other, they shall be separated by a distance atleast equal to or greater than half the diameter of pipe subject to a minimum of 450 mm.

The laying of pipes on the prepared concrete foundation shall start from the outlet and proceed towards the inlet and be completed to the specified lines and grades. The pipes shall be fitted and matched so that when laid they form a drain with a smooth uniform invert.

Any pipe found defective or damaged during laying shall be removed at the cost of the Contractor.

5A.5.15.5 Jointing

All the joints shall be made with care so that their interior face is smooth and consistent with the interior surface of the pipes. The ends of the pipes should be so shaped as to form a self-centering joint with jointing space 13 mm wide. The jointing space shall be filled with cement mortar (1 cement to 2 sand) mixed sufficiently dry to remain in position when forced with a trowel or rammer. Care shall be taken to fill all voids and excess mortar shall be removed. After finishing, the joints shall be kept covered and damp for at least four days.

5A.5.15.6 Back filling

Trenches shall be backfilled with selected murum as per specifications given in this part. Backfilling upto 0.3 metre above the top of pipe shall be carefully done and murum shall be thoroughly consolidated under the haunches of the pipe.

5A.5.16.1 Slab Culvert

Measurement of insitu concrete work shall be as specified in Section 4 of this specifications.

Measurement of masonry shall be as specified in Section 8 of this specifications.

Bitumen at locations of contact with concrete surface shall be measured in square metres over area covered in plan and the rates shall include cleaning the surfaces, applying in two coats, etc., as specified.

Graded gravel free draining backfill shall be measured in cubic metres and the rate shall include supplying, backfilling, etc., as specified.

Measurement for weep holes shall be running metres and the rates shall include providing and fixing in rubble masonry walls with necessary concrete cushioning to lines and levels as specified.

5A.5.16.2 Pipe Drains

Ancillary works such as excavation, backfilling, laying P.C.C below pipe, etc., shall be paid for separately, as provided under respective clauses.

Chapter – 5A.6

5A.6 - STRUCTURAL STEEL WORK

5A.6.1. Applicable Codes and Specifications

The supply, fabrication, erection and painting of structural steel works shall comply with the following specifications, standards and codes unless otherwise specified herein. All standards, specifications and codes of practices referred to herein shall be the latest editions including all applicable official amendments and revisions.

1.	IS:110	Ready Mixed paint, brushing, grey filler for enamels for use over primers.
2.	IS:158	Ready Mixed paint, Brushing, Bituminous, Black, Lead free, Acid, Alkali and heat resisting.
3.	IS:159	Ready Mixed paint, Brushing, Acid resisting for protection against acid fumes, colour as required.
4.	IS:341	Black Japan, Types A, B and C
5.	IS : 800	Code of Practice for General Construction in Steel
6.	IS : 801	Code of Practice for Use of Cold Formed Light Gauge Steel Structural Members in General Building Construction
7.	IS : 803	Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded storage tanks
8.	IS : 806	Code of Practice for Use of Steel Tubes in General Building Construction
9.	IS : 808	Dimensions for Hot Rolled Steel sections
10.	IS : 814	Covered Electrodes for Manual Metal Arc Welding of Carbon and Carbon Manganese Steel
11.	IS : 816	Code of Practice for use of Metal Arc Welding for General construction in Mild Steel
12.	IS : 822	Code of Procedure for Inspection of Welds
13.	IS : 1161	Steel Tubes for structural purposes
14.	IS : 1182	Recommended Practice for Radiographic examination of Fusion – Welded Butt Joints in Steel Plates

15.	IS : 1200	Method of Measurement in Building Civil Works
16.	IS : 1239	Mild steel tubes, tubulars and other Wrought steel fittings Part 1 – Mild steel tubes Part 2 – Mild steel tubulars and other wrought steel pipe fittings
17.	IS : 1363 (Parts 1 to 3)	Hexagon Head Bolts, Screws and Nuts of product Grade C (Size range M5 to M64)
18.	IS : 1367 (All parts)	Technical Supply Conditions for Threaded Fasteners
19.	IS : 1477	Code of Practice for Painting of (Parts 1&2) Ferrous Metals in Buildings
20.	IS : 1573	Electroplated Coating of Zinc on Iron and Steel
21.	IS : 1852	Rolling and Cutting Tolerances for Hot Rolled Steel Products
22.	IS : 1977	Structural Steel (Ordinary Quality)
23.	IS : 2062	Steel for General Structural Purposes
24.	IS : 2074	Ready Mixed Paint, Air drying, Red Oxide Zinc Chrome and Priming
25.	IS:2339	Aluminium paint for general purposes, in Dual container
26.	IS : 2595	Code of Practice for Radiographic Testing
27.	IS : 2629	Recommended Practice for Hot Dip Galvanising of Iron and Steel
28.	IS : 2633	Method of Testing Uniformity of Coating on Zinc Coated Articles
29.	IS:2932	Specification for enamel, synthetic, exterior, type 1, (a) undercoating, (b) finishing
30.	IS:2933	Specification for enamel, exterior, type 2, (a) undercoating, (b) finishing
31.	IS : 3502	Steel Chequered Plate
32.	IS : 3658	Code of Practice for Liquid Penetrant Flaw Detection
33.	IS : 3757	High Strength Structural Bolts
34.	IS : 4000	High Strength Bolts in Steel Structure – Code of Practice
35.	IS : 4736	Hot Dip Zinc coating on Mild steel tubes
36.	IS : 4759	Hot Dip Zinc coating on Structural Steel and other Allied products

37.	IS : 5334	Code of Practice for Magnetic Particle Flaw Detection of Welds
38.	IS : 5369	General Requirements for Plain Washers and Lock Washers
39.	IS : 5372	Taper Washers for Channels
40.	IS : 5374	Taper Washer for 1 Beams
41.	IS:5905	Sprayed aluminium and zinc coatings on Iron and Steel.
42.	IS:6005	Code of practice for phosphating of Iron and Steel.
43.	IS : 6158	Recommended Practice for Safeguarding against Embrittlement of Hot Dip Galvanised Iron and Steel
44.	IS : 6159	Recommended Practice for Design and preparation of Material Prior to Galvanising
45.	IS : 6610	Heavy Washers for Steel Structures
46.	IS : 6745	Methods for Determination of Weight of Zinc Coating on Zinc coated Iron and Steel Articles
47.	IS : 7205	Safety Code for Erection of Structural Steel Work
48.	IS : 7215	Tolerances for Fabrication of Steel Structures
49.	IS : 8500	Structural Steel-microalloyed (medium and high strength qualities)
50.	IS : 9595	Recommendations for Metal Arc Welding of Carbon and Carbon Manganese Steel
51.	IS:9862	Specification for ready mixed paint, brushing, bituminous, black, lead free, acid, alkali, water & chlorine resisting.
52.	IS:13183	Aluminium paint, Heat resistant.
53.	AISC	Specifications for Design, Fabrication and Erection of Buildings

5A.6.2. Steel Materials

Steel materials shall comply with the codes referred to in Sub-Clause 6.1.

All materials used shall be new, unused and free from defects.

Steel conforming to IS:1977 shall be used only for the following :

Fe310-0(St 32-0)	:	For general purposes such as door/window frames, grills, steel gates, handrails, fence posts, tee bars and other non-structural use.
Fe410-0(St 42-0)	:	For structures not subjected to dynamic loading other than wind loads such as : Platform roofs, foot over bridges, building, factory sheds etc.
Fe10-0(St 42-0)	:	Grade steel shall not be used a) If welding is to be employed for fabrication b) If site is in severe earthquake zone c) If plastic theory of design is used

5A.6.3. Drawings prepared by the Contractor

The Contractor shall prepare all design, fabrication and erection drawings for the entire work. All the drawings for the entire work shall be prepared in metric units. The drawings shall preferably be of one standard size and the details shown there in shall be clear and legible.

The Contractor shall not commence detailing unless Engineer's design drawings are officially released for preparation of shop drawings. The Contractor shall be responsible for the correctness of all fabrication drawings. Fabrication drawings shall be revised by the Contractor to reflect all revisions in design drawings as and when such revisions are made by the Engineer.

All fabrication drawings shall be submitted to the Engineer for approval.

No fabrication drawings will be accepted for Engineer's approval unless checked and approved by the Contractor's qualified structural engineer and accompanied by an erection plan showing the location of all pieces detailed. The Contractor shall ensure that connections are detailed to obtain ease in erection of structures and in making field connections.

Fabrication shall be started by the Contractor only after Engineer's approval of fabrication drawings. Approval by the Engineer of any of the drawings shall not relieve the Contractor from the responsibility for correctness of engineering and design of connections, workmanship, fit of parts, details, material, errors or omissions of any and all work shown thereon. The Engineer's approval shall constitute approval of the size of members, dimensions and general arrangement but shall not constitute approval of the connections between members and other details.

The drawings prepared by the Contractor and all subsequent revisions etc. shall be at the cost of the Contractor for which no separate payment will be made.

5A.6.4. Fabrication

5A.6.5.1 General

All workmanship and finish shall be of the best quality and shall conform to the best approved method of fabrication. All materials shall be finished straight and shall be machined/ground smooth true and square where so specified. All holes and edges shall be free of burrs. Shearing and chipping shall be neatly and accurately done and all portions of work exposed to view shall be neatly finished. Unless otherwise approved by the Employer's Representative, reference may be made to relevant IS codes for providing standard fabrication tolerance. Material at the shops shall be kept clean and protected from weather.

5A.6.5.2 Connections

Shop/field connections shall be as per approved fabrication drawings.

In case of bolted connections, taper washers or flat washers or spring washers shall be used with bolts as necessary. In case of high strength friction grip bolts, hardened washers be used under the nuts or the bolt heads whichever are turned to tighten the bolts. The length of the bolt shall be such that at least one thread of the bolt projects beyond the nut, except in case of high strength friction grip bolts where this projection shall be at least three times the pitch of the thread.

In all cases where bearing is critical, the unthreaded portion of bolt shall bear on the members assembled. A washer of adequate thickness may be provided to exclude the threads from the bearing thickness, if a longer grip bolt has to be used for this purpose.

All connections and splices shall be designed for full strength of members or loads. Column splices shall be designed for the full tensile strength of the minimum cross section at the splice.

All bolts, nuts, washers, electrodes, screws etc., shall be supplied/brought to site 10% in excess of the requirement in each category and size. Rates shall cover the cost of this extra quantity.

All members likely to collect rain water shall have drain holes provided.

5A.6.5.3 Straightening

All materials, shall be straight and, if necessary, before being worked shall be straightened and/or flattened by pressure and shall be free from twists. Long plates shall be straightened by passing through a mangle or leaving rolls and structural shapes by the use of mechanical or hydraulic bar/ section straightening machines. Heating or forging shall not be resorted to without the prior approval of the Employer's Representative in writing.

5A.6.5.4 Cutting

Cutting may be shearing, cropping, sawing or machine flame cutting if permitted by the Employer's Representative. All re-entrant comers shall be shaped notch-free to a radius of atleast 12mm. Sheared or cropped edges shall be dressed to a beat workmanlike finish and shall be free from distortion and burrs. The kerf on machine flame cut edges shall be removed. Where machine flame cutting is permitted for high tensile steel, special care shall be taken to leave sufficient margin and all flame hardened material shall be removed by machining/ edge planning. Hand flame cutting shall be undertaken only if so permitted by the Employer's Representative and shall only be carried out by and expert in such work. Hand flame cut edges shall be ground smooth and straight.

5A.6.5.5 Rolling and Forming

Plates, channels, R.S.J. etc., for circular bins, bunkers, hoppers, gantry girders, etc., shall be accurately laid off and rolled or formed to required profile/shape as called for on the drawings. Adjacent sections shall be match-marked to facilitate accurate assembly, welding and erection in the field.

5A.6.5.6 Punching and Drilling

Holes in secondary members such as purlins, girts, lacing bars, etc may be punched nail size through materials not over 12 mm thick. Holes must be clean cut, without burr or ragged edges. Holes for all other connections shall be drilled accurately and the burrs removed effectively. Where several parts are to be connected to very close tolerances, such parts shall be first assembled, then tightly clamped together and drilled through. Sub-punching may be permitted before assembly, provided the holes are Punched 3 mm smaller in diameter than the required size and reamed after assembly to the full diameter. The thickness of material punched shall not, even in such case, exceed 16 mm. When batch-drilling is carried out in one operation through two or more separable parts, these parts shall be separated after drilling and the burrs removed. Holes for turned and fitted bolts shall be drilled to a slightly smaller diameter and reamed to a diameter equal to the nominal diameter of the shank or barrel subject to H 8 tolerances specified in IS: 919. Where reamed members are taken apart for shipping or handling, the respective pieces reamed together shall be so marked that they may be reassembled in the same position in the final setting up. No inter-change of reamed parts will be permitted, Poor matching, over-drilling, and ovality in holes shall be a cause for rejection. Burning holes with gas is strictly prohibited.

5A.6.5.7 High Strength Friction Grip Bolting

High strength friction grip bolts and nuts shall conform to IS: 3757. Installation of high strength friction grip bolts in joints shall comply with IS: 4000. The diameter of the bolt hoes must not be more than 1.5mm larger than the nominal diameter of the bolt. All contact surfaces in a connection including those associated with the not heads, nut in a washers, shall be free of scale, burrs, dirt and other foreign matter tending to inhibit uniform sealing of the joint components/ nuts and washers need not be removed. All fasteners in a joint shall be tightened to a tension equal to or greater than the specified proof load show in the following table, either by the calibrated method or the turn-of-nut method.

Bolt Size	Proof Load (Kg)	
	Bolts to I.S. 37S7-BG	Bolts to I.S. 3757-1 OK
M16	9120	10790
M20	14700	17150
M22	18180	21210
M25	21180	23710
M27	27450	32130
M33	41640	48580

Tightening may be achieved by use of pneumatic powered impact wrenches, long-handled manual torque wrenches with or without torque multipliers or electric wrenches. A hardened washer shall be placed under the element being turned. Bolts shall be tightened at the most rigid portion of the joint, proceeding towards the free edges.

When using the calibrated wrench method, adjustable power impact wrenches and manual torque wrenches shall be calibrated to induce bolt tensions of 5 percent in excess of the proof load values for each size of bolt to be used in installation. Every wrench shall be calibrated by having it tighten a minimum of three bolts of the same diameter, in a hydraulic tension measuring device. Calibration shall be repeated whenever a wrench is required to tighten a different size bolt, or at least once each working day if there is no change in the bolt size. Impact wrenches shall be set so as to shall or cut at the torque effort corresponding to the prescribed fastener tension. When manual torque wrenches are used, the torque indication corresponding to the calibrating tension shall be determined and taken as the job standard. Torque measurements shall be read while the turned element is in tightening motion. As subsequent tightening of bolts in any particular assembly is liable to loosen bolts already tightened, all bolts must be "Touched up".

When using the turn of nut method a sufficient number of bolts must initially be 'snugged up' to bring the connection components into full contact, by either a standard power impact wrench or an ordinary spud wrench. Snug tight condition shall indicate the point at which the turned element ceases to rotate freely and the impact wrench begins to impact or if a common spud wrench is employed, snug tightness shall mean the position resulting from the full effort of a man. Subsequently, the remaining bolts in the joints shall also be brought to snug tightness. All nuts and projecting bolt points shall be matchmarked in this starting position and all bolts in the joints relevant specifications for the bolt length and type of connection proceeding in an orderly fashion from the most rigid portion of the joint, towards the free edges.

If the finger-tight condition is used as a starting point extra full turns shall be taken to correspond to one-half turn from the snug tight position.

Load indicating bolts or load indicating washers may be used if so approved by the Employer's Representative in writing.

Inspection after tightening of bolts shall be carried out as stipulated in the appropriate standards depending upon the method of tightening and the type of bolt used.

5A.6.5.8 Welding

Electrodes for shielded-arc manual welds shall comply with the requirement of IS: 814, and shall be approved make.

The electrodes for manual arc welding shall be suitable for use in the position and type of work, as laid down in the above specifications and as recommended by the manufacturers. Electrodes classification group 1 or 2 as given in IS: 814 shall be used for welding steel conforming to IS: 2062 and electrodes shall conform to IS: 1442 for steel conforming to IS: 8500. Joints in materials above 20 mm thick and all-important connections shall be made with low hydrogen electrodes.

The wire and flux combination for submerged arc welding shall conform to the requirements for the desired application as laid down in IS: 3613. The weld metal deposited by the submerged arc process shall have mechanical properties not less than that specified by the relevant standard.

Electrodes flux covering shall be sound and unbroken. Broken or damaged coating shall cause the electrodes to be discarded. Covered electrodes for manual-arc welding shall be properly stored in an oven prior to use in a manner recommended by the manufacturer and only an hour's quota shall be issued to each welder from the oven.

Electrodes larger than 5 mm diameter shall not be used for root-runs in butt welds.

Welding plant and accessories shall have capacity adequate for the welding procedure laid down and shall satisfy appropriate standards and be of approved make and quality. The Contractor shall maintain all welding plant in good working order. All the electrical plant in connection with the welding operation shall be properly and adequately earthed and adequately earthed and adequate means of measuring the current shall be provided.

All welds shall be made only by welders and welding operators who have been properly trained and previously qualified by tests to perform the type of work required as prescribed in the relevant applicable standards.

All welds shall be free from defects like blow holes, slag inclusions, lack of penetration, undercutting, cracks etc. All welds shall be cleaned of slag or flux and show uniform sections, smoothness of weld metal, featheredges without overlap and freedom from porosity.

Fusion faces and surfaces adjacent to the joint or a distance of at least 50 mm on either side shall be absolutely free from grease, paint, loose scales, moisture or any other substance which might interfere with welding or adversely affect the quality of the weld. Joint surfaces shall be smooth, uniform and free from fins, tears, laminations, etc. Preparation of fusion faces shall be done in accordance with the approved fabrication drawings by shearing, chipping, machining or machine flame cutting except that shearing shall not be used for thickness over 8 mm.

In the fabrication of cover-plated beams and built up members all shop splices in each component part shall be made before such component part is welded to other parts of the member. Wherever weld reinforcement interferes with proper fit-up between components to be assembled for welding, these welds shall be ground flush prior to assembly.

Members to be joined by fillet welding shall be brought and held as close together as possible and in no event shall be separated by more than 3 mm. If the separation is 1.5 mm or greater the fillet weld size shall be increased by the amount of separation. This shall only apply in the case of continuous welds. The fit-up of joints at contact surfaces which are not completely sealed by welds shall be close enough to exclude water after painting.

The separation between the two surfaces of lap joints and butt joints with backing plate shall not exceed 1.5 mm. Abutting parts to be butt welded shall be carefully aligned and the correct root gap maintained throughout the welding operation. Misalignments greater than 25 % of the thickness of the thinner plate or 3mm,whichever is smaller, shall be corrected and in making the correction the parts shall not be drawn into a slope sharper than 2° (1 in 27.5).

Pre-qualified welding procedures recommended by appropriate welding standards and know to provide satisfactory welds shall be followed .A welding procedure shall be prepared by the Contractor and submitted to the Employer's Representative for approval before start of welding. This shall include all details of welding procedures with reference to provisions of IS: 9595 and IS: 4353.

Approval of the welding procedure by the Employer's Representative shall not relieve the Contractor of his responsibility for correct and sound welding without undue distortion in the finished structure.

Submerged arc, automatic or semi-automatic welding shall generally be employed. Only where it is not practicable to use submerged arc welding, manual arc welding may be resorted to.

Voltage and current (polarity of direct current is used) shall be set accordingly to the recommendations of the manufacturer of the electrode being used and suitability of thickness of material, joint form etc.

The work shall be positioned for flat welding wherever practicable and overhead weld shall be avoided.

No welding shall be done when the surface of the member is wet, not during periods of high wind unless the welding operator and the work are properly protected.

In joints connected by fillet welds, the minimum sizes of single fillet welds or first runs and minimum full sizes of fillet welds shall conform to the requirements of IS: 816 and IS: 9595.

All complete penetration butt welds made by manual arc welding, except when produced with the aid of backing material or welded in flat position, from both sides in square-edge material not over 8mm thick with root opening not less than one-half the thickness of the thinner part joined, shall have the root of the initial layer gouged out on the back side before welding is a started from that side, and shall be so welded as to secure sound metal and complete fusion throughout the entire cross section.

Butt welds shall be terminated at the ends of a joint in a manner that will ensure their soundness. Where abutting parts are 20 mm or more than in thickness, run-on and run-off plates with similar edge preparation and having a width not less than the thickness of the thicker part jointed shall be used. These extension pieces shall be removed upon completion of the weld end, the ends of the weld made smooth and flush with the abutting parts. Where the abutting parts are thinner than 20 mm, the extension pieces may be omitted but the ends of the butt welds shall then be chipped or gouged out to sound, metal and side welded to fill up the ends to the required reinforcement.

Each layer of a multiple layer weld except root and surface runs may be moderately peened with light blows from a blunt tool. Care shall be exercised to prevent scaling or flaking of weld and base metal from over peening.

No welding shall be done on base metal at a temperature below 5°C. Base metal shall be preheated to the temperature given in the table below prior to tack welding or welding. When base metal not otherwise required to be preheated, is at a temperature below 0°C, it shall be preheated to at least 20°C prior to tack welding or welding. Preheating shall bring the surface of the base metal within 75 mm of the point of welding to the specified preheat temperature, and this temperature shall be maintained as minimum inter pass temperature while welding is in progress.

Thickness of the thickest part at point of welding	Minimum preheat & inter pass temperature			
	Other than low-hydrogen welding electrodes		Low hydrogen welding electrodes	
	IS: 2062 Steel	IS: 8500 Steel	IS:2062 Steel	IS: 8500 Steel
Up to 20 mm incl.	None	Welding	None	10°C
Over 20 mm to 40 mm incl.	65°C	With this process not allowed	10°C	65°C
Over 40 mm to 63mm incl.	110°C		95°C	not
Over 63 mm	150°C		110°C	150°C

Electrodes other than low-hydrogen electrodes shall not be permitted for thickness of 75 mm and above.

Before commencing fabrication of a member or structure in which welding is likely to result in distortion and/or locked up stresses, a complete programmed of fabrication, assembly and welding shall be made and submitted to the Employer's Representative for approval. Such a programme shall include, besides other appropriate details, full particulars in regard to the following:

a) proposed pre-bending in components such as flanges and pre-setting of joints to offset expected distortion.

b) Make up of sub-assemblies proposed to be welded before incorporation in final assembly.

c) Proposed joint forms, classification of wore and flux or covered electrodes, welding process including fitting and welding sequence with directions in which freedom of movement is to be allowed.

d) Proposed number, spacing and type of strong backs, details of jigs and fixtures for maintaining proper fit up and alignment during welding.

e) Any other special features like assembling similar members back to back or stress relief.

So desired by the Employer's Representative, mock up welding shall be carried out at the Contractor's cost to establish the efficiency of the proposed programme, with any modification suggested by the Employer's Representative, in limiting distortion and/ or residual stress to acceptable levels. Such modification will not relieve the Contractor of any of his responsibilities,

5A.6.5.9 Inspection of Welds

All welds shall be inspected for flaws as described elsewhere under "Inspection".

In case the tests uncover defective work, the Contractor shall correct such defects at his own cost, and prove the soundness of rectified work.

The correction of defective welds shall be carried out as directed by the Employer's Representative without damaging the parent metal. When a crack in the weld is removed, magnetic particle inspection or any other equally positive means as prescribed by the Employer's Representative shall be used to ensure that the whole of the crack and material up to 25 mm beyond each end of the crack has been removed. Cost of all such tests and operations incidental to correction shall be to the Contractor's account.

5A.6.5.10 Tolerances

The dimensional and weight tolerances for rolled shapes shall be in accordance with IS : 1852 for indigenous steel and equivalent applicable codes for imported steel. The tolerances for fabrication of structural steel shall be as per IS : 7215.

Cutting, punching, drilling, welding and fabrication tolerances shall be generally as per relevant IS codes.

5A.6.5. Inspection and Testing

5A.6.6.1 General

The Contractor shall give due notice to the Employer’s Representative in advance of the works being made ready for inspection. All rejected material shall be promptly removed from the shop and replaced with new material for the Employer’s Representative’s inspection. The fact that certain material has been accepted at the Contractor’s shop shall not invalidate final rejection at site by the Employer’s Representative if it fails to conform to the requirements of these specifications, to be in proper condition or has fabrication inaccuracies which prevent proper assembly nor shall it invalidate any claim which the Employer may make because of defective or unsatisfactory materials and/or workmanship.

No materials shall be painted or despatched to site without inspection and approval by the Employer’s Representative unless such inspection is waived in writing by the Employer’s Representative.

The Contractor shall provide all the testing and inspection services and facilities for shop work except where otherwise specified.

For fabrication work carried out in the field the same standard of supervision and quality control shall be maintained as in shop fabricated work. Inspection and testing shall be conducted in a manner satisfactory to the Employer’s Representative.

Inspection and tests on structural steel members shall be as set forth below.

5A.6.6.2 Material Testing

If mill test reports are not available for any steel materials the same shall be tested by the Contractor to the Employer’s Representative’s satisfaction to demonstrate conformity with the relevant specification.

5A.6.6.3 Tests on Welds

Magnetic Particle Test

Where welds are examined by magnetic particle testing, such testing shall be carried out in accordance with relevant IS codes. If heat treatment is performed, the completed weld shall be examined after the heat treatment. All defects shall be repaired and retested. Magnetic particle tests shall be carried out using alternating current. Direct current may be used with the permission of the Employer's Representative.

Liquid Penetrant Inspection

In the case of welds examined by Liquid Penetrant Inspection, such tests shall be carried out in accordance with relevant IS Code. All defects shown shall be repaired and rechecked.

Radiographic Inspection

All full strength butt welds shall be radiographed in accordance with the recommended practice for radiographic testing as per relevant IS code.

5A.6.6.4 Dimensions, Workmanship & Cleanliness

Members shall be inspected at all stages of fabrication and assembly to verify that dimensions, tolerances, alignment, surface finish and painting are in accordance with the requirements shown in the Contractor's approved fabrication drawings.

5A.6.6.5 Test Failure

In the event of failure of any member to satisfy inspection or test requirement, the Contractor shall notify the Employer's Representative. The Contractor must obtain permission from the Employer's Representative before any repair `is undertaken. The quality control procedures to be followed to ensure satisfactory repair shall be subject to approval by the Employer's Representative.

The Employer's Representative has the right to specify additional testing as he deems necessary, and the additional cost of such testing shall be borne by the Employer, only in case of successful testing.

The Contractor shall maintain records of all inspection and testing which shall be made available to the Employer's Representative.

5A.6.6. Shop Matching

For structures like bunkers, tanks, etc. shop assembly is essential. For other steel work, such as columns along with the tie beams/bracings may have to be shop assembled to ensure satisfactory fabrication, obtaining of adequate bearing areas etc., if so desired by the Employer's Representative. All these shop assemblies shall be carried out by the Contractor.

5A.6.7. Marking of Members

After checking and inspection, all members shall be marked for identification during erection. This mark shall correspond to distinguishing marks on approved erection drawings and shall be legibly painted and stamped on it. The erection mark shall be stamped with a metal dye with figures at least 20 mm high and to such optimum depth as to be clearly visible.

All erection marks shall be on the outer surface of all sections and near one end, but clear of bolt holes. The marking shall be so stamped that they are easily discernible when sorting out members. The stamped marking shall be encircled boldly by a distinguishable paint to facilitate easy location.

Erection marks on like pieces shall be in identical locations. Members having lengths of 7.0 m or more shall have the erection mark at both ends.

5A.6.8. Errors

Any error in shop fabrication which prevents proper assembling and fitting up of parts in the field by moderate use of drift pins or moderate amount of reaming will be classified by the Employer's Representative as defective workmanship. Where the Employer's Representative rejects such material or defective workmanship, the same shall be replaced by materials and workmanship conforming to these Employer's Requirements by the Contractor, at no cost to the Employer.

5A.6.9. Site Operations

The Contractor shall complete all preliminary works at site well before the arrival of structural steel, such as establishment of a well-equipped and adequately staffed site office, stores, unloading gantry, unloading pre-assembly yard, labour quarters if any, electrical and water connections, electrical winches, derricks, cranes, compressors, all tools and tackles, rivet guns, welding sets, torque wrenches, spud wrenches, staging, etc., as well as experienced erection and supervisory personnel as part of this contract and any other work that may be necessary so as to start erection immediately afte.r the arrival of the first batch of steel on site.

The Contractor shall furnish at his own expense, the necessary non-inflammable staging and hoisting materials or equipment required for the erection work and shall remove and take them away after completion of the job. The Contractor shall also provide necessary passageways, fences, safety belts, helmets, lights and other fittings to the satisfaction of the Employer's Representative and to meet the rules of local authorities and for protection to his men and materials. A licensed electrician shall be kept on the job for the entire duration of the work to maintain the Contractor's electrical equipment and connections.

The Contractor shall protect all existing plant, structures, piping, conduits, equipment and facilities against damage during erection. Any damage caused by contractor shall be rectified entirely at his cost, to the satisfaction of the Employer's Representative. If work has to be carried out adjacent to existing switch yards or electrical installations which are live, the Contractor must ensure suitable safety precautions in consultation with Employer's Representative.

If a portion of the work of the project area cannot be made available to the Contractor for his activities due to operations being carried out by other agencies, he shall suitably modify his sequence of operations so as to continue work without interruption. The Contractor shall work in co-ordination with other agencies working on the project site and plan his work suitably so as not to hinder the progress of construction at site.

5A.6.10. Acceptance of Steel, its Handling & Storage

The Contractor shall carefully check the steel to be erected at the time of acceptance. Any fabrication defects observed should be brought to the notice of the Employer's Representative.

No dragging of steel shall be permitted. All steel shall be stored 300mm above ground on suitable packing to avoid damage. It shall be stored in the order required for erection, with erection marks visible. All storage areas shall be prepared and maintained by the Contractor. Steel shall not be stored in the vicinity of areas where excavation or grading will be done and, if so stored temporarily, this shall be removed by the Contractor well before such excavation and/or grading commences to a safe distance to avoid burial under debris.

Scratched or abraded steel shall be given a coat of primer in accordance with these Employer's Requirements for protection after unloading and handling prior to erection. All milled and machined surfaces shall be properly protected from rust/corrosion by suitable coating and also from damage.

5A.6.11. Anchor Bolts & Foundations

The Contractor shall carefully check the location and layout of anchor bolts embedded in foundations constructed, to ensure that the structures can be properly erected as shown on the drawings. Any discrepancy in the anchor bolts/foundation shall be reported to the Employer's Representative.

Levelling of column bases to the required elevation may be done either by providing shims or three nuts on the upper threaded portion of the anchor bolt. All shim stock required for keeping the specified thickness of grout and in connection with erection of structures on foundations, crane brackets or at any other locations shall be of good M.S. plates and shall be supplied by the Contractor at his cost.

A certain amount of cleaning of foundations and preparing the area is considered normal and shall be carried out by the Contractor at no extra cost.

Where beams bear in pockets or on walls, bearing plates shall be set and levelled as part of the work. All grouting under column base plates or beam bearing plates will be carried out by the Contractor.

5A.6.12. Assembly & Connections

Field connections may be effected either by riveting, bolting, welding or by use of high strength friction grip bolts as shown on the design and erection drawings.

All field connection work shall be carried as per the drawings prepared by the Contractor. All bolts, nuts, washers, rivets, electrodes required for field connections shall be supplied by the Contractor.

All assembling shall be carried on a level platform.

Drifts shall be used only for drawing the work to proper position and must not be used to such an extent as to damage the holes. Size of drifts larger than the normal diameter of hole shall not be used. Any damaged holes or burrs must be rectified to the satisfaction of the Employer's Representative.

Corrections of minor misfits and reasonable amount of reaming and cutting of excess stock from rivets shall be considered as a part of erection. Any error in the shop, which prevents proper fit on a moderate amount of reaming and slight chipping or cutting, shall be immediately reported to the Employer's Representative.

5A.6.13. Erection

All structural steel shall be erected as shown on the drawings prepared by the Contractor. Proper size steel cable slings, etc., shall be used for hoisting. Guys shall not be anchored to existing structures, foundations, etc., unless so permitted by the Employer's Representative in writing. Care shall be taken to see that ropes in use are always in good condition.

Steel columns in the basement, if any, are to be lowered and erected carefully with the help of a crane and/or derrick without damaging the basement walls or floor.

Structural steel frames shall be erected plumb and true. Frames shall be lifted at points such that they are not liable to buckle and deform. Trusses shall be lifted only at node points. In the case of trusses, roof girders, all of the purlins and wind bracing shall be placed simultaneously and the columns shall be erected truly plumb on screed bars over the pedestals. All steel columns and beams shall be checked for plumb and level individually before and after connections are made. Temporary bracings shall be introduced wherever necessary to take care of all loads to which the structure may be subjected, including erection equipment and the operation thereof. Such bracings shall be left in place as long as may be required for safety and stability.

Chequered plates shall be fixed to supporting members by tack welding or by countersunk bolts as shown/specified in relevant drawings and/or as approved by the Employer's Representative. The edges shall be made smooth and no burrs or jagged ends shall be left. While splicing, care should be taken so that there is continuity in pattern between the two portions. Care should also be taken to avoid distortion of the plate while welding. The erection of chequered plates shall include :

(a) Welding of stiffening angles/vertical stiffening ribs

(b) Cutting to size and making holes to required shape wherever necessary to allow service piping and/or cables to pass through

(c) Splicing as shown in relevant drawings

(d) Smoothening of edges

(e) Fixing of chequered plates by tack welding or by countersunk bolts

(f) Providing lifting hooks for ease of lifting.

As erection progresses, the work shall be securely bolted to take care of all dead load, wind, seismic and erection stresses.

No riveting or welding or final bolting shall be done until the structure has been properly aligned and approved by the Employer's Representative. No cutting, heating or enlarging of the holes shall be carried out without the prior written approval of the Employer's Representative.

Test certificates shall be furnished by the Contractor.

5A.6.14.1 General

The Employer's Representative shall have free access to all parts of the job during erection and all erection shall be subjected to his approval. In case of faulty erection, all dismantling and re-erection required will be at the Contractor's cost. No paint shall be applied to rivet heads or field welds or bolts until these have been approved by the Employer's Representative.

5A.6.14. Tolerances

5A.6.15.1 General

Tolerances mentioned below shall be achieved after the entire structure or part thereof is in line, level and plumb.

5A.6.15.2 Columns

Deviation of column axes at foundation top level with respect to true axes :

(a)	In longitudinal direction	±5 mm
(b)	In lateral direction	±5 mm

Deviation in the level of bearing surface of columns at foundation top with respect to true level ±5mm

Out of plumbness (verticality) of column axis from true vertical axis, as measured at column top:

(a)	For columns upto and including 15 metres in height	±1/1000 of column height in mm or ±15 mm whichever is less
(b)	For columns exceeding 15 metres in height	±1/1000 of column height in mm or ±20 mm whichever is less

Deviation in straightness in longitudinal and transverse planes of column at any point along the height	±1/1000 of column height in mm or ±10 mm whichever is less
Difference in erected position of adjacent pairs of columns along length or across width of building prior to connecting trusses/beams with respect to true distance	±10mm
Deviation in any bearing or seating level with respect to true level	±5 mm
Deviation in differences in bearing level	±10 mm

of a member on adjacent pair of columns both across and along the building

5A.6.15.3 Trusses And Beams

Shift at the centre of span of top chord member with respect to the vertical plane passing through the centre of bottom chord	±1/250 of height of truss in mm or ±15 mm whichever is less
Lateral shift of top chord of truss at the centre of span from the vertical plane passing through the centre of supports of the truss	±1/1500 of span of truss in mm or ±15 mm whichever is less
Lateral shift in location of truss from its true vertical position	±10 mm
Lateral shift in location of purlin true position	±5 mm
Deviation in difference of bearing levels of trusses or beams from the true difference	i) ±20 mm for trusses ii) For beams : Depth < 1800mm : ±6mm Depth > 1800mm : ±10mm
Deviation in sag in chords and diagonals of truss between node points	1/1500 of length in mm or 10mm whichever is smaller
Deviation in sweep of trusses, beams etc. in the horizontal plane to a maximum of 10 mm	1/1000 of span in mm subject

5A.6.15.4 Crane Girders & Rails

Shift in the centre line of crane rail with respect to centre line of web of crane girder	±5 mm
Shift in plan of alignment of crane rail with respect to true axis of crane rail at any point	±5 mm
Difference in alignment of crane rail in plan measured between any two points 2 metres apart along rail	±1 mm

Deviation in crane track with respect to	
Time gauge	
(a) For track gauges upto and	
Including 15 metres	±5 mm
(b) For track gauges more than	± [5 + 0.25 (S-15)]
15 metres	where S in metres is true gauge
Deviation in the crane rail level at any	±1/1200 of the gauge distance or
point from true level	±10mm whichever is less
Difference in the crane rail actual levels	±2 mm
between any two points 2 metres apart along the rail length	
Difference in levels between crane track Rails at	
(a) Supports of crane girders	±15 mm
(b) Mid span of crane girders	± 20 mm
Relative shift of crane rail surfaces at a	2 mm subject to grinding of
joint in plane and elevation	surfaces for smooth transition
Relative shift in the location of crane	1/1000 of track gauge S in
stops (end buffers) along the crane tracks	mm subject to maximum
with track gauge S in mm	of 20 mm

5A.6.15. Clean up of Work site

During erection, the Contractor shall at all times keep the working and storage areas used by him free from accumulation of waste materials or rubbish. Before completion of erection, he shall remove or dispose of in a satisfactory manner all temporary structures, waste and debris and leave the premises in a condition satisfactory to the Employer's Representative.

5A.6.16. Painting

5A.6.17.1 General

After steel has been erected, all bare and abraded spots, rivet heads, field welds, bolt heads and nuts shall be spot painted with primer. Before paint is applied, the surface shall be dry and free from dust, dirt, scale and grease. All surfaces inaccessible after erection shall receive two coats of the approved paint before erection.

5A.6.17.2 Surface Treatment

All the surfaces of steel work to be painted shall be thoroughly cleaned of all loose mill scale, rust, grease, dirt and other foreign matter. The workmanship shall generally conform to the requirements of IS 1477- Part I.

Oil and grease removal shall be carried out either by solvent cleaning or by using alkali type degreasing agents. To remove grease material the surface shall be cleaned with solvents containing emulsifier. After cleaning, the surface shall be washed with water. When the surface has cement pelter or salts, the cleaning shall be done with strong alkalis. After cleaning, water rinsing and subsequent passivation by dilute chromic acid rinsing shall be carried out to ensure that no traces of alkali is left on the surface. The procedure for cleaning by above mentioned methods shall be as per manufacturer's instructions.

De-rusting and descaling of steel shall be carried out either manually, mechanically or chemically.

Manual or Hand Tool Cleaning

Loose mill scale, loose rust and loose paint shall be removed by wire brushing, scrapping, chipping, rubbing with abrasive paper or steel wool. This method shall not be employed when the surface has firmly adhering mill scale. After hand tool cleaning, the surface shall be rubbed with sand paper so as to ensure that no loose material exists and the surfaces shall be dusted off.

Mechanical Cleaning

Power Tool Cleaning

This shall be carried out by employing power operated wire brushes. Power tool cleaning shall be resorted to only if sand/shot blasting is not possible/permissible and high quality of surface preparation is required.

The surface prior to treatment shall have been cleaned of dust and grease and heavier layers of rust removed by chipping.

The power tool cleaning shall remove loose mill scale and rust by adopting very thorough scrapping, grinding and machine brushing. After the surfaces are cleaned by compressed air, it shall have a pronounced metallic sheen.

Flame Cleaning

Hard mill scale and rust shall be removed through Oxy- acetylene flame. The work shall be carried out by trained workmen to ensure that only mill scale is removed without heating the parent steel. The work shall be carried out carefully on welded surfaces so that the strength of weld is not affected due to heating.

Sand Blasting and Shot Blasting

Sand/shot blasting shall only be carried out after removal of grease, oil and other contaminants. The work shall be carried out by impinging under pressure of air, a jet of sharp sand or granulated steel (steel grits) on to the metal surface. The process shall ensure complete removal of rust and firmly adhering mill scale. Special care shall be taken on weld areas to remove flux and spatter. Blasting shall ensure an even colour of the surface and the surface shall have silver grey colour. Precautions shall be taken when sand or shot blasting of light gauge steel surfaces to ensure that buckling does not occur due to continuous impingement of sand or steel shots under high velocity.

Sand/shot blasting shall be adopted for structures which are exposed to corrosive conditions for which superior paint protection is to be adopted. The finished surfaces shall conform to the requirements of Sa 2.5 or Sa 3 as per Swedish Standard SIS-05-5900 as required.

As sand blasting causes dust nuisance, necessary clearance shall be obtained by the Contractor from the Competent authorities prior to commencing sand blasting.

Chemical Cleaning (Pickling)

The cleaning shall be done by pickling in sulphuric, hydrochloric or phosphoric acids. Pickling shall be carried out in accordance with detailed procedure as given in IS 6005.

Washing after pickling shall remove all traces of the acids. All work pieces shall be thoroughly inspected and in particular the inaccessible corners.

All surfaces shall be cleaned thoroughly as per manufacturers specification before application of primer.

5A.6.17.3 Materials

Primer paint

Anti-corrosive primers shall be either lead based or lead free types. Red lead primer shall conform to IS 102 and red oxide zinc chrome primer shall conform to IS 2074.

Finish Paint

Epoxy primer and epoxy paint shall be of the type as specified from an approved manufacturer.

Chlorinated rubber based paint shall be of the manufacture as specified or any equivalent approved manufacture.

All the materials shall be of the best quality from an approved manufacturer. The Contractor shall obtain prior approval of the Employer's Representative for the brand of manufacture and the colour/shade prior to procurement for usage in the works.

Primer and finish paints shall be compatible with each other to avoid cracking and wrinkling. As such it is recommended that the primer and finish paint shall be from the same manufacturer.

The colour and shade shall be conforming to IS Standards referred to in Appendix 'D' of IS 1477-Part II. To facilitate choosing the correct shade number from the alternatives available, the Contractor shall adopt trial painting in small patches in consultation with and as approved by the Employer's Representative.

All paint delivered to the fabrication shop/site shall be ready mixed, in original sealed containers, as packed by the manufacturer. Thinner shall not be permitted for usage unless specifically approved so by the Employer's Representative.

Paints shall be stirred thoroughly to keep the pigment in suspension.

The Contractor shall arrange for testing of paints as per relevant Indian Standards in an approved laboratory whenever the Employer's Representative requires the tests to be carried out for each batch of paints. Test results shall be submitted to the Employer's Representative for approval.

5A.6.17.4 Workmanship

The type and the number of coats of the primer paint and finish paint shall be as specified.

Painting shall be carried out only on thoroughly dry surfaces.

No painting shall be done in frosty/foggy weather or when the humidity is high enough to cause condensation on the surface to be painted. Paint shall not be applied when the temperature of the surface to be painted is at 5deg.C or lower.

Primers shall adhere to the surface firmly and offer a key to the subsequent coats.

Workmanship shall generally conform to requirements specified in IS:1477-Part II.

It is essential to ensure that immediately after preparation of the surfaces, the first coat of primer paint shall be applied by brushing and working it well to ensure a continuous film. After the first coat becomes hard dry a second coat of primer shall be applied by brushing.

Structural steel surfaces shall be given the first coat of primer at shop and the second coat after it is erected in position. Further, any abraded surfaces of the first coat during transport from shop to site and during erection shall be provided with a touch-up coat of the primer.

The dry film thickness of each coat of primer shall be not less than 25 microns.

Application of finishing paints shall be carried out within the shortest possible time interval after primer since the primer coats are too thin to give adequate corrosion protection of the steel surface over a long duration.

Filler coats shall be applied to fill dents and to obtain a smooth finish wherever necessary. Only factory prepared filler suitable for steel work shall be used. Fillers prepared by whiting and linseed oil by craftsmen at site shall not be used. Application of filler shall be done with good `putty knife' and necessary skill. Filler applied shall be just sufficient to fill the depression or unevenness and it shall be restricted to the minimum. It shall be applied in thin layers. In filling depression or unevenness, as many coats as are necessary may be applied allowing each layer to dry hard. The hardened coat shall be cut down by wet rubbing before the subsequent coat is applied. Where necessary, filler coats shall be applied over the undercoats also.

Painting shall be carried out either by brushing or by spraying. The Contractor shall procure the appropriate quality of paint for this purpose as recommended by the manufacturer.

After the second coat of primer is hard dry, the entire surface shall be wet rubbed cutting down to a smooth uniform surface. When the surface becomes dry, the undercoat of paint of optimum thickness shall be applied by brushing/spraying with minimum of brush marks. The coat shall be allowed to hard-dry. The under coat shall then be wet rubbed cutting down to a smooth finish, taking adequate care to ensure that at no place the undercoat is completely removed. The surface shall then be allowed to dry.

The first finishing coat of paint shall be applied by brushing or by spraying and allowed to hard-dry. The gloss from the entire surface shall then be gently removed and the surface dusted off. The second finishing coat shall then be applied by brushing or by spraying.

At least 24 hours shall elapse between the application of successive coats. Each coat shall vary slightly in shade and shall be approved by the Employer's Representative, prior to applying the next coat.

Minimum dry film thickness of each coat of finish paint of synthetic enamel shall be 25 microns. Minimum dry film thickness of other finish paints shall be as specified in the respective item of work.

The thickness of film shall be measured by an Elcometer to be supplied by the Contractor. The Contractor shall calibrate the Elcometer frequently for different settings. Necessary calibrating accessories should be kept ready for calibration / testing of the Elcometer at any time.

Epoxy primer and epoxy paint shall be applied within the specified pot life all as per recommendations of the manufacturer.

Surfaces inaccessible after assembly shall receive two coats of primer prior to assembly.

Surfaces inaccessible after erection, including top surfaces of floor beams, supporting grating or chequered plate shall receive one additional coat of finish paint over and above the number of coats specified prior to erection.

Portion of steel members embedded/to be encased in concrete shall not be painted. Joints to be site welded shall have no shop paint for at least 50mm from the welding zone. Similarly, the steel surfaces shall not be painted in areas where connection is by use of friction grip bolts. On completion of the joint, the surfaces shall receive the painting as specified.

Maintenance painting of steel structures will become necessary if the painting already carried out shows signs of chalking, hairline cracking, deep checking, fine checking, peeling, blistering and rusting. It is essential that same quality of paint as specified earlier need be adopted to ensure compatibility. The general workmanship for maintenance painting shall conform as per Clause.7 of IS 1477 – Part II.

The Contractor shall provide suitable protection as necessary to prevent paint finishes from splashing on equipment, floors, walls, etc.

5A.6.17. Method of Measurement

For the purpose of payment, the weight of the actual, completed structures shall be calculated from the approved drawings for different items of work. Contractor shall submit to Employer relevant material list containing weight of each item.

No allowance will be permitted for weights of rivets, bolts, washers, screws etc. in calculating the weight of the completed structure. No allowances will be permitted for galvanizing, welding or for rolling margins. One tonne for the purpose of payment shall mean One Metric Tonne i.e. 1000 kg.

The weight of a member made out of standard rolled sections such as beams, channels, angles, etc. shall be based on the weight of the member given in IS 808, without deducting for hole, notches, bevel cuts, etc. Where a component consists of a cut joist or channel, the full weight of the rolled section shall be considered only if more than half the depth of the section is used. Otherwise only half the section unit weight shall be taken. Deductions shall be made in the weight of gussets/plates including chequered plates for skew cuts, notches and openings of 900 sq.cm. or larger.

For gussets/plates used in trusses, bracings, columns, beams etc. the area shall be that of the minimum circumscribing rectangle, except as stated above.

The weight of any built-up member shall be separated into the weight of each component.

Erection bolts installed by erector may be left in position on completion of erection; however, no additional payment shall be made either for supply or use of such bolts. If erection bolts are removed after erection is complete, holes shall be plug welded and ground smooth. No extra payment shall be made for such plug welding.

Painting work shall not be measured separately, if primer painting and/or primer and finish painting is deemed to be included in the scope of the item of work of fabrication and erection of structural steel since the rate per tonne of steel is deemed to include for painting as specified.

In cases where primer and/or finish painting work as specified is carried out on erected structural steel executed by a different agency, the method of measurement for painting shall be on the basis of tonnage of steel erected. For this purpose, the tonnage of erected steel as certified for payment to the different agency shall be considered as the basis and no measurement will be carried out separately.

5A.6.18. Galvanising of Structural Steel

5A.6.19.1 Galvanising Plant

Prior approval shall be obtained from Employer / Engineer if galvanising is proposed to be carried out outside Contractor's plant.

5A.6.19.2 Workmanship

After all shop work is complete, all structural materials shall be punched with the erection mark and be hot-dip galvanised. Before galvanising, the steel shall be thoroughly cleaned of any paint, grease, rust, acid or alkali or such other foreign matters as are likely to interfere with the galvanising process or with the quality and durability of the zinc coating. Pickling shall be very carefully done and shall be proper.

The weight of the zinc coating shall be at least 0.610 kg/sq.m unless specified otherwise. Stub members and members for grillage type footing shall have heavier zinc coating not less than 0.80 kg/sq.m.

The galvanised surface shall consist of a continuous and uniformly thick coating of zinc, firmly adhering to the surface of steel. The finished surface shall be clean and smooth, and shall be free from defects like discoloured patches, bare spots, unevenness of coating, spelter which is loosely attached to the steel, globules, spiky de S:2633 unless specified otherwise.

All galvanised members shall be treated with Sodium dichromate solution or an approved equivalent after galvanising, so as to prevent white storage stains.

Galvanising of each member shall be carried out in one complete immersion. Double dipping shall not be permitted. However, in case of members over 7.5 M long, the Contractor shall take prior approval of Engineer for double dipping. When the steel section is removed from the galvanising kettle, excess spelter shall be removed by 'bumping'.

Wherever galvanised bolts, nuts locknuts, washers, accessories etc. are specified, they shall be hot-dip galvanised. Spring washers shall be electro-galvanised. Excess spelter from bolts, nuts, etc. shall be removed by centrifugal spinning. Rechasing of bolt threads after galvanising shall not be permitted. Nuts, however, may be tapped, but not to cause appreciable rocking of the nuts on the bolts. Readily available GI nuts, bolts and washers conforming to galvanising requirements may also be used.

Defects in certain members indicating presence of impurities in the galvanising bath in quantities larger than that permitted by the specifications, or lack of quality control in any manner in the galvanising plant, shall render the entire production in the relevant shift liable to rejection.

Contractor shall ensure that galvanising is not damaged in transit. In the event of occurrence of any damages Contractor shall at his own cost adopt scrapping and regalvanising the member to satisfy the specific requirements.

Chapter – 5A.7

5A.7 - WATER SUPPLY AND SANITARY WORKS

5A.7.1. Applicable Codes

The following standards and codes are made a part of this Employer's Requirement. All standards, codes of practice referred to herein shall be the latest editions including all official amendments and revisions.

IS : 210	:	Specification for grey iron castings
IS : 269	:	Specification for 33 grade ordinary portland cement
IS : 383	:	Specification for coarse and fine aggregates from natural sources for concrete
IS : 432	:	Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement (Part-I & II)
IS : 456	:	Code of Practice for plain and reinforced concrete
IS : 458	:	Concrete Pipes (with and without reinforcement).
IS : 516	:	Methods of tests for strength of concrete
IS : 554	:	Dimensions for pipe threads where pressure tight joints are required on the threads.
IS : 651	:	Salt glazed stoneware pipes and fittings.
IS : 774	:	Flushing Cisterns for water closets and urinals (valveless siphonic type)
IS : 781	:	Sand-cast brass screw-down bib taps and stop taps for water services.
IS : 783	:	Code of practice for laying of concrete pipes.
IS : 1068	:	Electroplated coatings of nickel and chromium of iron and steel.
IS : 1077	:	Specification for common burnt clay building bricks
IS : 1239	:	Mild steel tubes (Part I) and mild steel tubulars and other wrought steel pipe fittings (Part II)
IS : 1536	:	Centrifugally cast (spun) iron pressure pipes for water, gas and sewage.
IS : 1626	:	Asbestos cement building pipes, gutters and fittings (spigot and socket types).
IS : 1703	:	Copper Alloy float valves (horizontal plunger type) for water supply purposes.
IS : 1726	:	Cast iron manhole covers and frames.
IS : 1729	:	Sand cast iron spigot and socket soil, waste and ventilating pipes, fittings and accessories.
IS : 1742	:	Code of practice for buildings drainage

IS : 1786	:	Specification for high strength deformed steel bars and wires for concrete reinforcement
IS : 2116	:	Specification for sand for masonry mortars
IS : 2212	:	Code of practice for brickwork
IS : 2250	:	Code of practice for preparation and use of masonry mortars
IS : 2326	:	Automatic flushing cisterns for urinals
IS : 2470	:	Code of practice for design and construction of septic tanks (Parts I & II)
IS : 2556	:	Vitreous sanitary appliances (Part I to Part XV)
IS : 2963	:	Specification for copper alloy waste fittings for wash basins and sinks
IS : 3006	:	Specification for chemically resistant glazed stoneware pipes and fittings
IS : 3311	:	Waste plug and its accessories for sinks and wash basins
IS : 3495	:	Methods of tests of burnt clay building bricks
IS : 4111	:	Code of practice for ancillary structures in sewerage system manholes
IS : 4127	:	Code of Practice for laying of glazed stoneware pipes
IS : 5329	:	Code of practice for sanitary pipe work above ground for buildings
IS : 5382	:	Specification for rubber sealing rings for gas mains, water mains and sewers
IS : 5455	:	Specification for cast iron steps for manholes

5A.7.2. Sanitary Installation

The work shall be carried out complying in all respects with any specific requirements of the local body in whose jurisdiction the work is situated, and as approved by the Employer's Representative.

Any damage caused to the building, or to installations therein, either due to negligence on the part of the Contractor, or due to actual requirements of the work, shall be made good and the building or the installation shall be restored to its original condition by the Contractor.

All sanitary and plumbing work shall be carried out by licensed plumbers.

All sanitary appliances including sanitary fittings, fixtures, toilet requisites shall be of size, and design as approved by the Employer's Representative.

All white glazed porcelain fixtures, such as wash basin, sink drain board, water closet pan, urinal, `P' trap etc. shall have hard durable white glazed finish. They shall be free from cracks and other glazing defects. No chipped porcelain fixtures shall be used.

Joints between iron and earthenware pipes shall be made perfectly air and water tight by caulking with neat cement mortar.

5A.7.3. Indian Type Water Closet

This shall be the long pan pattern with separate footrests made of white glazed earthenware, white glazed vitreous china or of white glazed fire clay. The general requirements shall conform to IS:2556 (Parts III and X). Each pan shall have an integral flushing rim of suitable type. It shall also have an inlet or supply horn for connecting the flush type. The flushing rim and inlet shall be of the self-draining type. It shall have a weephole at the flushing inlet to the pan. The flushing inlet shall be in the front, unless otherwise approved by the Employer's Representative. The inside of the bottom of pan shall have sufficient slope from the front towards the outlet and the surface shall be uniform and smooth enable easy and quick disposal while flushing. The exterior surface shall be unglazed and sufficiently rough or grooved at right angles to the axis of the outlet. Pans shall be provided with a trap `P' or `S' type with a minimum 50 mm water seal and 50 mm dia. vent horn. Pan shall be laid at the correct location and level over a bed of lime concrete using brick aggregates (1 part lime mortar to 2 parts brick bats with lime mortar to 2 parts of sand) or cement-sand admixture as specified in the drawings.

5A.7.4. European Type Water Closet

Water closets shall be either of white glazed earthenware, white grazed vitreous china or white glazed fire clay as specified and shall be of "Siphonic Wash down type" conforming to IS.2556 (Part VIII). The closets shall be of one piece construction with approved plastic/bakelite seat and cover. Each water closet shall have 4 fixing holes having a minimum diameter of 6.5 mm for fixing to floor and shall have an integral flushing rim of suitable type. It shall also have an inlet of supply horn for connecting the flush pipe. The flushing rim and inlet shall be of the self-draining type. The water closet shall have a weephole at the flushing inlet. Each water closet shall have an integral trap with either "S" or "P" outlet with at least 50 mm water seal. The water closets shall have an antisiphonage 50 mm dia. vent horn on the outlet side of the trap. The inside of water closets and traps shall be uniform and smooth in order to ensure in efficient flush. The serrated part of the outlet shall not be glazed externally. The water closet when sealed at the bottom of the trap in line with the back plate, shall be capable of holding not less than 10 litres of water between the normal water level and the highest possible water level of the water closet installed.

5A.7.5. Urinals

Urinals shall be of the bowl pattern, either flat back or angle back type lipped in front. They shall be of white glazed earthenware, white glazed vitreous china or white glazed fire clay, and of size as specified conforming to IS.2556 (Part VI). The urinals shall be of one piece construction. Each urinal shall be provided with not less than two fixings holes of a minimum dia. of 6.5 mm on each side. Each urinal shall have an integral flushing box rim of suitable type and inlet or supply horn for connecting the flush pipe. The flushing rim and inlet shall be of the self-draining type. It shall have a weephole at the flushing inlet of the urinal. At the bottom of the urinal, an outlet horn for connecting to an outlet pipe shall be provided. The exterior of the outlet horn shall not be glazed and the surface shall be provided with grooves at right angles to the axis of the outlet to facilitate fixing to the uniform and smooth throughout to ensure efficient flushing. The bottom of pan shall have sufficient slope from the front, towards the outlet such that there is efficient draining of the urinal. The waste fittings shall be chromium plated.

5A.7.6. Wash Basins

Wash basins shall be of white glazed earthenware, white glazed vitreous china or white glazed fire clay as approved by the Employer's Representative and conforming to IS.2556

Type	Size
Flat Back	630 x 450 mm
Flat Back	550 x 400 mm

Wash basins shall be of one piece construction, including a combined overflow. All internal angles shall be designed so as to facilitate cleaning. Each shall have a rim sloping inside towards the bowl on all sides except skirting at the back. Basins shall be provided with single or double tap holes as approved. The tap holes shall be square. A suitable tap hole button shall be supplied if one tap hole is not required in installation. Each basin shall have a circular waste hole to which the interior of basin shall drain. The waste hole shall be either rebated or bevelled internally with diameter of 65 mm at top and a depth of 10 mm to suit a waste plug having 64 mm diameter. Each basin shall be provided with a non-ferrous 32 mm waste fittings. Stud slots to receive the brackets on the under side of the wash basins shall be suitable for a bracket with stud not exceeding 13 mm diameter, 5 mm high and 305 mm from the back of basin to the centre of the stud. The stud slots shall be of depth sufficient to take 5 mm stud. Every basin shall have an integral soap holder recess or recesses which shall fully drain into the bowl. The position of the chain stay-hole shall not be lower than the overflow slot. A slot type of overflow having an area of not less than 5 sq.cm. shall be provided and shall be so designed as to facilitate cleaning of the overflow. The Employer's Requirements for waste plug, chain and stay shall be the same as given for sinks.

All the waste fittings shall be chromium plated. Bottle trap shall conform to IS. 5434. The chromium plating shall be of service grade No. 2 conforming to IS.1068.

5A.7.7. Sinks

The sinks shall be of white glazed earthenware, white glazed vitreous china or white glazed fire clay as approved by the Employer's Representative conforming to IS.2556 (Part V) and shall be of the following sizes:

450 x 300 x 150 mm

600 x 450 x 200 mm

They shall be of one piece construction, including a combined overflow. The floor of the sink shall gently slope towards the outlet. The outlet shall in all cases be suitable for waste fittings having flange of 64 mm diameter and the waste hole shall have a minimum diameter of 65 mm at the bottom to suit the waste fittings. The waste hole shall be either rebated or bevelled having a depth of 10 mm. Each sink shall be provided with a non-ferrous 40 mm dia. waste fitting. The sink shall have overflow of the weir type and the inverts shall be 30 mm below the top edge. Each sink shall be provided with a waste plug, of suitable dia. chain and stay. The plug shall be of rubber or other equally suitable material and shall be water tight when fitted. Plug chains shall be of brass wire chromium plated. It shall have an overall length from the collar to the stay of not less than 300 mm. There shall be a triangular or D shackle at each end, one of which shall be brazed to the plug and the other securely fixed to the stay. The 150 mm long shank of the waste shall be threaded conforming to the requirements of IS.2556 for sinks only. The waste fittings and plug fittings shall be chromium plated. The chromium plating shall be of service grade No.2 conforming to IS.1068.

5A.7.8. Flushing Cisterns

The flushing cisterns shall be automatic or manually operated, high level or low level, as approved by the Employer’s Representative. For water closets and urinals high level cistern is intended to operate with minimum height of 125 cm and a low level cistern a maximum height of 30 cm between the top of the pan and the underside of the cistern. They shall be of cast iron, glazed earthenware, or pressed steel complying iron, glazed requirement of IS.774. Automatic flushing cistern for urinals shall conform to IS.2326.

5A.7.9. Cast Iron Soil Waste and Vent Pipes and Fittings

All cast iron pipes and fittings shall be of uniform thickness with strong and deep sockets, free from flaws, air holes, cracks, sand holes and other defects and conform to IS.1536 . The diameter approved shall be internal diameter of pipe. The pipes and fittings shall be true to shape, smooth and cylindrical and shall ring clearly when struck over with a light hand hammer. All pipes and fittings shall be properly cleaned of all foreign material before being fixed.

All plug bends of drainage pipes shall be provided with inspection and cleaning caps, covers, which shall be fixed with nuts and screws. Pipes shall be fixed to the wall by W.I. or M.S. holder bat clamps, unless projecting ears with fixing holes are provided at socket end of pipe. The pipes shall be installed, truly vertical or to the lines and slopes as indicated. The clamps shall be fixed to the walls by embedding their hooks in cement concrete blocks (1:2:4) 10 cm x 10 cm making necessary holes in the walls at proper places. All holes and breakages shall be made good. The clamps shall be kept 25 mm clear of the finished face of the walls to facilitate cleaning and painting of pipes.

The annular space between the socket and spigot shall be filled with a gasket of hemp or spun yarn soaked in neat cement slurry. The joint shall then be filled with stiff cement mortar 1:2 (1 cement : 2 fine sand) well pressed with caulking tool and finished smooth on top at an angle of 45°. The joint shall be kept wet for not less then 7 days by tying a piece of gunny bag kept moist. Joints shall be perfectly air tight as well as water tight.

C.I. pipes and fittings which are exposed shall be first cleaned and then painted with a coat of red leadprimer. Two coats of zinc paint with white base and mixed with pigment of required colour to get the approved shade shall be given over the base primer coat.

The thickness of fittings and their socket and spigot dimensions shall conform to the thickness and dimensions approved for the corresponding sizes of straight pipes.

The connection between the main pipe and branch pipes shall be made by using branches and bends with access for cleaning. Floor traps shall be provided with 25 mm dia. puff pipe where the length of the waste is more than 1800 mm or the floor trap is connected to a waste stack through bends.

All cast iron pipes and fittings including joints shall be tested by a smoke test to the satisfaction of the Employer’s Representative and left in working condition after completion. The smoke test shall be carried out as stated under :

Smoke shall be pumped into the pipe at the lowest and from a smoke machine which consists of a bellow and a burner. The material usually burnt is greasy cotton waste which gives out a clear pungent smoke which is easily detectable by sight as well as by smell if there is a leak at any point of the pipeline.

Water test and air test shall be conducted as stipulated in IS.5329.

5A.7.10. Asbestos Cement (A.C) Pipes and Fittings

All A.C. soil, waste, vent pipes, and fittings shall conform to IS.1626. The pipes shall have spigot and socket ends. These shall be composed of an inert aggregate consisting of clean asbestos fibre cemented together by ordinary portland cement conforming to IS.269, or portland blast furnace slag cement conforming to IS.455. No organic material shall be added to the composition.

The pipes shall be straight and the ends of the pipes and fittings shall be finished square to their axes. The finished pipes and fittings shall be true and smooth, their inner and outer surfaces shall be concentric. They shall be in all respects sound, homogenous and free from impurities or other imperfections.

The permissible tolerance on the thickness and external dimensions of pipes and fittings including hydraulic test pressure of the pipes and fittings shall conform to IS.1626.

All AC pipes and fittings shall be of approved make and with necessary accessories, wherever required. The diameter wherever approved for pipes and fittings shall be clear internal diameter. All gaps between pipes and fittings and walls shall be filled with cement mortar 1:3 neatly finished. All pipes and fittings shall be supported with standard fixing brackets.

The annular space between the socket and spigot shall be filled with a gasket of hemp of spun yarn soaked in tar. The joint shall then be filled with stiff cement mortar 1:2 (1 cement : 2 fine sand) well pressed with caulking tools and finished smooth on top with neat cement paste at an angle of 45º. The joint shall be kept wet for not less than 7 days by tying a piece of gunny bag kept moist. Joints shall be perfectly air-tight as well as water-tight.

Pipes and fittings shall be tested with a smoke test as approved in Clause 7.9.

5A.7.11. Galvanised Mild Steel (G.I) Pipes

The pipes shall be galvanised mild steel welded pipes and seamless screwed and sockets tubes conforming to the requirements of IS.1239, for medium grade. They shall be of the diameter (nominal bore) approved. The sockets shall be designated by the respective nominal bores of the pipes for which they are intended. The pipes and sockets shall be finished neatly, well galvanised on both inner and outer surfaces, and shall be free from cracks, surface flaws, laminations and other defects. All screws, threads shall be clean and well cut. The ends shall be cut cleanly and square with the axis of the tube.

All screwed tubes and sockets shall have pipe threads conforming to the requirements of IS.554. Screwed tubes shall have taper threads while the sockets shall have parallel threads.

The fittings shall be of malleable cast iron or mild steel tubes complying with all the appropriate requirements as approved for pipes. The fittings shall be designated by the respective nominal bores of the pipes for which they are intended. The fittings shall have screw threads at the ends conforming to the requirements of IS.554.

Female threads on fittings shall be parallel and male threads (except on running nipples and collars of unions) shall be tapered.

The pipes and fittings shall be inspected at site before use to ascertain that they conform to the specification. The defective pipes shall be rejected. Where the pipes have to be cut or rethreaded, the ends shall be carefully filled out so that no obstruction to bore is offered. The ends of the pipes shall then be threaded conforming to the requirements of IS.554 with pipe dies and taps carefully in such a manner as will not result in slackness of joints when the two pieces are screwed together. The taps and dies shall be used only for straightening bent and damaged screw threads and shall not be used for turning of the threads so as the make them slack, water tight joint. The screw- thread of pipes and fittings shall be protected from damage until they are fitted.

The pipes shall be cleaned and cleared of all foreign matter before being laid. In jointing the pipes, the inside of the socket and the screwed end of the pipes shall be oiled and rubbed over with white lead and a few turns of spun yarn wrapped around the screwed end of the pipe.The end shall then be screwed in the socket, tee, etc., with the pipe wrench. Care should be taken that all pipes and fittings are properly jointed so as to make the joints completely water tight and pipes are kept at all times free from dust and dirt during fixing. Burrs from the joint shall be removed after screwing. After laying, the open ends of the pipes shall be temporarily plugged to prevent access of soil or any other foreign matter.

Any threads exposed after jointing shall be painted or in the case of underground piping thickly coated with approved anticorrosive paint to prevent corrosion.

For internal work the galvanised iron pipes and fittings shall run on the surface of the walls or ceiling (not in chase) unless otherwise specified. The fixing shall be done by means of standard pattern holder bat clamps, keeping the pipes about 1.5 cm clear of the wall. Pipes and fittings shall be fixed truly vertical/horizontal. When it is found necessary to conceal the pipes, chasing may be adopted or pipes fixed in the ducts of recesses etc. provided there is sufficient space to work on the pipes with the usual tools. The pipes shall not ordinarily be buried in walls or solid floors. Where unavoidable, pipes may be buried for short distances provided adequate protection is given against damage, but the joints in pipes shall not be buried. M.S. pipe sleeve shall be fixed at a place where a pipe is passing through a wall or floor for reception of the pipe and to allow freedom for expansion/contraction and other movements/maintenance. In case the pipe is embedded in walls or floors it should be painted with anti-corrosive bitumastic paint of approved quality. The pipe should not come in contact with lime mortar or lime concrete as the pipe is affected by lime. Under the floors the pipes shall be laid in layer of sand filling or as approved by the Employer's Representative.

G.I. pipes with socket and spigot ends shall be provided with lead caulked joints wherever specified and the joints shall conform to the requirements of IS.3114.

The work of excavation and backfilling shall be done true to line and gradient in accordance with general Employer's Requirements for earthworks in trenches for pipes laid underground.

The pipes shall be laid on a layer of 10.0 cm sand and filled upto 15 cm above the pipes. A sand cushion of 15cm on either side of the pipe shall also be provided. The remaining portion of the trench shall then be filled with excavated earth. The surplus earth shall be got rid of as directed. when excavation is done in rock the bottom shall be cut deep enough to permit the pipes to be laid on a cushion of sand 75 mm minimum.

The pipes and fittings after they are laid and jointed shall be subjected to hydrostatic pressure test as approved by the Employer's Representative and shall satisfactorily pass the test. Pipe line system shall be tested in sections as the work proceeds, keeping the joints exposed for inspection. Pipes shall be slowly and carefully charged with water allowing all air to escape. All draw off taps shall then be closed and water pressure gradually raised to test pressure. Care shall be taken to ensure that pressure gauge is accurate and preferably should have been recalibrated before the test. Pump used having been stopped, the section of the pipeline shall maintain the test pressure for at least half an hour. Any joints or pipes found leaking shall be removed and replaced by the Contractor.

The G.I. pipe line shall be cut to the required length at the position where the meter and stop cock are required to be fixed. The ends of the pipes shall be threaded. The meter and stop cock shall be fixed in position by means of connecting pipe, G.I. nuts, sockets, etc. The stop cock shall be fixed near the inlet of the water meter. The paper disc inserted in the ripples of the meter shall be removed and meter installed exactly horizontally or vertically and with the arrow cast on the body of the meter pointing in the direction of flow. Care shall be taken that the factory seal of the meter is not disturbed. Whenever the meter is to be fixed to a newly fitted pipe line, the pipe line will have to be completely washed before fixing the meter. For this purpose, a connecting piece of pipe equal to the length of the meter is to be fixed on the new pipe line. The water shall be allowed to flow completely to wash the pipe line and then the meter installed as described above by replacing the connecting piece.

5A.7.12. Stoneware pipes and fittings

All pipes with spigot and socket ends shall conform to IS.651/3006 and shall be of grade `A'. These shall be sound, free from visible defects such as fine cracks or hair cracks. The glaze of the pipes shall be free from crazing. The pipes shall give a sharp clear note when struck with a light hammer.

The following information shall be clearly marked on each pipe and fitting :

(a) Internal diameter;

(b) Grade;

(c) Date of manufacture;

(d) Name of manufacturer or his registered trade-mark or both.

All pipes and fittings shall have ISI mark.

Jointing of GSW pipes and fittings shall be done as per the requirements of the following Employer's Requirements and the relevant IS. After jointing, extraneous material if any, shall be removed from the inside of the pipes and fittings and the newly made joints shall be thoroughly cured. In case, rubber sealing rings are used for jointing, these shall conform to IS : 5382.

5A.7.12.1 Spigot and Socket Joint (Cement Joint)

The spigot of each pipe shall be slipped home well into the socket of the pipe previously laid and adjusted in the correct position. In each joint, spun yarn soaked in neat cement slurry or tarred gasket shall be passed around the joint and inserted in it by means of a caulking tool. More skeins of yarn or gasket shall be added if necessary and shall be well caulked. Yarn or gasket so rammed shall not occupy more than one- fourth of the depth or socket.

Cement mortar (1:1) shall be slightly moistened and carefully inserted by hand into the remaining space of the joint after caulking of yarn or gasket. The mortar shall than be caulked into the joint with a caulking tool. More cement mortar shall be added until the space of joint has been completely filled with tightly caulked mortar. The joint shall then be finished of neatly outside the socket at an angle of 45 degrees. The cement mortar joints shall be cured at least for seven days before testing. The approximate quantity of cement required for each joint for certain common sizes of pipes are given below for guidance :

Nominal diameter of pipe (mm)	**Cement (kg)**
150	1.5
200	2.0
250	2.5
300	3.25
350	4.5
400	5.5
450	6.5

5A.7.12.2 Spigot and Socket Joint (Bituminous Joint)

The general requirements for this type of joint shall be as specified in 13.12.1 The material for jointing shall consist of composition of asphalt and sand in the ratio of 1:7. Asphalt and sand shall be boiled together and filled into the socket in a molten state with the aid of special moulds.

5A.7.12.3 Spigot and Socket Joint (Rubber Ring Joint)

The pipe with the rubber ring accurately positioned on the spigot shall be pushed well home into the socket of the previously laid pipe by means of uniformly applied pressure with the aid of a jack or similar appliance. The rubber rings conforming to IS : 5382 shall be used, and the manufacturer's instructions shall be deemed to form a part of this Employer's Requirements. The rubber rings shall be lubricated before making the joint and the lubricant shall be soft soap water or an approved lubricant supplied by the manufacturer.

5A.7.12.4 Cleaning of Pipes

As soon as a stretch of GSW pipes has been laid complete from manhole to manhole or for a length as approved by the Employer's Representative, the Contractor shall run through the pipes both backward and forward a double disc or solid or closed cylinder 50 mm less in diameter than the internal diameter of pipes. The open end of an incomplete stretch of pipeline shall be securely closed as approved by the Employer's Representative to prevent entry of mud or silt etc.

If as a result of the removal of any obstruction the Employer's Representative considers that damages may have been caused to the pipe lines, he shall be entitled to order the length to be tested immediately. Should such test prove unsatisfactory the Contractor shall repair the pipeline and carry out such further tests as are required by the Employer's Representative.

It shall also be ascertained by the Contractor that each length from manhole to manhole or the length as approved by the Employer's Representative is absolutely clear and without any obstruction by means of visual examination of the interior of the pipeline suitably illuminated by projected sunlight or otherwise.

After laying and jointing of GSW pipes is completed the pipe line shall be tested as per the following Employer's Requirements and as approved by the Employer's Representative. All equipment for testing at work site shall be supplied and erected by the Contractor. Water for testing of pipeline shall be arranged by him. Damage during testing shall be the Contractor's responsibility and shall be rectified by him to the full satisfaction of the Employer's Representative. Water used for test shall be removed from pipes and not released to the excavated trenches.

After the joints have thoroughly set and have been checked by the Employer's Representative and before backfilling the trenches, the entire section of the sewer or storm water drain shall be proved by the Contractor to be water tight. Before commencing the hydraulic test, the pipelines shall be filled with water and maintained full for 24 hours by adding water, if necessary, under a head of 0.6 m of water. The test shall be carried out by suitably plugging the low end of the drain and the ends of connections, if any, and filling the system with water. A knuckle bend shall be temporarily jointed at the top end and a sufficient length of vertical pipe jointed to it so as to provide the required test head; or the top end may be plugged with a connection to a hose ending in a funnel which could be raised or lowered till the required head is obtained and fixed suitably for observation. The pipeline shall be subjected to a test pressure of at least 2.5 m head of water at the highest point of the section under test. The tolerance of two litres per centimeter of diameter per kilometer may be allowed during a period of 10 minutes. Any leakage including excessive sweating which causes a drop in the test water level will be visible and the defective part of the work should be removed and made good.

If any damage is caused to the pipeline during the execution of work or while cleaning/testing the pipeline as specified. The Contractor shall be held responsible for the same and shall replace the damaged pipeline and re-test the same to the full satisfaction of the Employer’s Representative.

Water for testing of pipeline shall be arranged by the Contractor.

5A.7.13. Stop Cock and Bib Cock

A bibcock (bibtap) is a draw off tap with a horizontal inlet and free outlet and stopcock (stop tap) is a valve with a suitable means of connections for insertion in a pipe line for controlling or stopping the flow. They shall be of specified size and shall be of the screw down type. The closing device should work by means of a disc carrying a renewable non-metallic washer, which shuts against water pressure on a seating at right angles to the axis of the threaded spindle which operates it. The handle shall be either crutch or butterfly type securely fixed to the spindle. The cocks shall open in anti-clockwise direction. When the bib cocks and stop cocks are required to be chromium plated, the chromium plating shall be of service Grade No. 2 conforming to IS.1068. in finish and appearance, the plated articles shall be free from plating defects such as blisters, pits, roughness and shall not be stained or discoloured.

These fittings shall be of brass heavy class, chromium plated (C.P) and of approved manufacture and pattern with screwed of flanged ends as specified. The fittings shall in all respects comply with the requirements of IS.781. The standard size of brass fittings shall be designated by the nominal bore of the pipe to which the fittings are attached. A sample of each kind of fitting shall be approved by the Employer’s Representative and all supplies made according to the approved samples.

All cast fittings shall be sound and free from laps, blow holes and fittings, both internal and external surfaces shall be clean, smooth and free from sand etc. Burning, plugging stopping or patching of the casting shall not be permitted. The bodies, bonnets, spindles and other parts shall be truly machined and when assembled the parts shall be axial, parallel and cylindrical with surfaces smoothly finished. The area of the waterway of the fittings shall not be less than the area of the nominal bore.

The fittings shall be fully examined and cleared of all foreign matter before being fixed. The fittings shall be fitted in the pipe line in a workman like manner. The joints between fittings and pipes shall be made leak- proof. The joints and fittings shall be leak proof when subjected to a pressure test approved by the Employer’s Representative and the defective fittings and joints shall be replaced or redone.

5A.7.14. Soak Pit

Soak pit shall be constructed at the location specified by the Employer’s Representative. Earthwork excavation shall be carried out to the exact dimensions. Brick masonry lining with open joints shall be constructed in the pit upto 150 mm below the outlet pipeline. Brick masonry in cement mortar 1:6 shall be constructed above this level upto ground. Well burnt brick aggregates of nominal size 40 mm to 80 mm and coarse sand shall be filled within the chamber. Construction of pit lining and filling of the brick ballast shall progress simultaneously.

5A.7.15. Manholes

5A.7.15.1 Location

Manholes shall be constructed at places approved by the Employer's Representative.

5A.7.15.2 Excavation

Excavation, shoring, dewatering etc. for the pits of manholes, laying of pipes and fittings/specials shall be done in accordance with Employer's Requirements described elsewhere in the document.

5A.7.15.3 Bed Concrete

The bed concrete for manholes shall be done in accordance with Employer's Requirements described elsewhere in the document.

5A.7.15.4 Bricks

Bricks used for construction of manholes shall conform to the relevant Indian Standards. They shall be sound, hard, homogeneous in texture, well burnt in kiln without being vitrified, table moulded, deep red, cherry or copper coloured, of regular shape and size and shall have sharp and square and parallel faces. The bricks shall be free from pores, chips, flaws or humps of any kind. Bricks containing unground particles and/or which absorb water more than 1/6th of their weight when soaked in water for twenty-four hours shall be rejected. Overburnt or underburnt bricks shall be liable to rejection. The bricks shall give a clear ringing sound when struck and shall have a minimum crushing strength of 50 kg/sq.cm. unless otherwise noted in drawings. The class and quality requirements of bricks shall be as laid down in IS : 1077.

The size of the brick shall be 23.0 x 11.5 x 7.5 cm. unless otherwise specified; but tolerance upto ± 3 mm in each direction shall be permitted. Only full size brick shall be used for masonry work. Brick bats shall be used only with the permission of Employer's Representative to make up required wall length or for bonding. Sample bricks shall be submitted to the Employer's Representative for approval and bricks supplied shall conform to approved samples. If required by the Employer's Representative, brick sample shall be tested as per IS : 3495 by Contractor. Bricks rejected by the Employer's Representative shall be removed from the Site within 24 hours.

5A.7.15.5 Cement Mortar

Mortar for brick masonry shall be prepared as per IS : 2250. Manholes shall be constructed in brick masonry with cement mortar (1:2) unless otherwise specified. Gauge boxes for sand shall be of such dimensions that one bag containing 50 kg. of cement forms one unit. The sand shall be free from clay, shale, loam, alkali and organic matter and shall be of sound, hard, clean and durable particles. Sand shall be as approved by the Employer's Representative. If required by the Employer's Representative sand shall be thoroughly washed till it is free of any contamination.

For preparing cement mortar, the ingredients shall first be mixed thoroughly in dry conditions. Water shall then be added and mixing continued to give a uniform mix of required consistency. Cement mortar shall be used within 25 minutes of mixing. Mortar left unused in the specified period shall be rejected.

The Contractor shall arrange for tests on mortar samples if so required by Employer's Representative. Retempering of mortar shall not be permitted.

5A.7.15.6 Brick Masonry

All bricks shall be thoroughly soaked in clean water for at least one hour immediately before being laid. The cement mortar for brick masonry work of manholes shall be in the proportion specified in 13.15.5. Brick work 230 mm thick and over shall be laid in English Bond unless otherwise specified. 115 mm thick brick work shall be laid with stretchers. For laying bricks, a layer of mortar shall be spread over the full width of suitable length of the lower course. Each brick shall be pressed into the mortar and shoved into final position so as to embed the brick fully in mortar. Bricks shall be laid with frogs uppermost.

All brickwork shall be plumb and square unless otherwise shown on drawing and true to dimensions shown. Vertical joints in alternate courses shall come directly one over the other and be in line. Horizontal courses shall be levelled. The thickness of brick courses shall be kept uniform. For walls of thickness greater than 230 mm both faces shall be kept in vertical planes unless otherwise specified. All interconnected brickwork shall be carried out at nearly one level (so that there is uniform distribution of pressure on the supporting structure) and no portion of the work shall be left more than one course lower than the adjacent work. Where this is not possible, the work shall be raked back according to bond (and not saw toothed) at an angle not exceeding 45 degrees. But in no case the level difference between adjoining walls shall exceed 1.25 M. Workmanship shall conform to IS : 2212.

Brick shall be so laid that all joints are well filled with mortar. The thickness of joints shall not be less than 6 mm and not more than 10 mm. The face joints shall be raked to a minimum depth of 12 mm by raking tools daily during the progress of work when the mortar is still green, so as to provide a proper key for the plastering to be done. When plastering is not required to be done, the joints shall be uniform in thickness and be struck flush and finished at the time of laying. The face of brickwork shall be cleaned daily and all mortar droppings removed. The surface of each course shall be thoroughly cleaned of all dirt before another course is laid on top. If mortar in the lower courses has begun to set, the joints shall be raked out to a depth of 12 mm before another course is laid.

5A.7.15.7 Cement Plaster

All joints in masonry shall be raked to a depth of 12 mm with hooked tool made for the purpose when the mortar is still green and in any case within 48 hours of its laying. The surface to be rendered shall be washed with fresh clean water free from all dirt, loose material, grease etc. and thoroughly wetted for 6 hours before plastering work is commenced. Concrete surfaces to be rendered will however be kept dry. The wall should not be too wet but only damp at the time of plastering. The damping shall be uniform to get uniform bond between the plaster and the wall.

The proportion of the cement mortar shall be as approved on relevant drawings. Cement shall be mixed thoroughly in dry condition and then just enough water added to obtain a workable consistency. The quality of water, sand and cement shall be as per relevant I.S. The mortar thus mixed shall be used immediately and in no case shall the mortar be allowed to remain for more than 25 minutes after mixing with water. Curing of plaster shall be started as soon as the applied plaster has hardened enough so as not to be damaged. Curing shall be done by continuously applying water in a fine spray and shall be carried out for at least 7 days.

lastering shall be done on both faces of brick masonry in cement mortar (1:2) and 20 mm thick unless otherwise specified. Plastering work shall be carried out in two layers, the first layer being 14 mm thick and the second layer being 6 mm thick. The first layer shall be dashed against the prepared surface with a trowel to obtain an even surface. The second layer shall then be applied and finished leaving an even and uniform surface, trowel finished unless otherwise approved by the Employer's Representative.

5A.7.15.8 Cement Concrete Channel

The channel for the manhole shall be constructed in cement concrete of M15 grade. Both sides of the channel shall be taken up to the level of the crown of the outgoing sewer. They shall be benched up in concrete and rendered in cement mortar (1:1) of 20 mm thickness and formed to a slope of 1 in 12 towards the channel.

5A.7.15.9 Pipe Entering or Leaving Manhole

Whenever a pipe enters or leaves a manhole, bricks on edge must be cut to a proper form and laid around the upper end of the pipe so as to form an arch. All around the pipes, there shall be a joint of cement mortar (1:2) 13 mm thick between it and the bricks.

5A.7.15.10 Cast Iron Steps

Cast iron steps shall be as per IS : 5455. The steps shall be of grey cast iron of grade 15 as per IS : 210. The steps shall be clean, well cast and they shall be free from air and sand holes, cold shuts and warpings. The portion of the step which projects from the wall of the manhole shall have a raised chequered design to provide an adequate non-slip grip. C.I. steps shall weigh not less than 4.5 kg each and shall be of 150 mm x 375 mm overall dimensions. These steps shall be coated with a black bituminous composition. The coating shall be smooth and tenacious. It shall not flow when exposed to a temperature of 63 degrees C and shall not be brittle as to chip of at temperature of 0 degree C.

Where the depth of invert of manhole exceeds 800 mm, cast iron steps of approved pattern shall be fixed in the brick work at the interval of 300 mm vertically and staggered at 380 mm horizontally centre to centre. In case of pipe diameter greater than 600 mm, box type C.I. steps weighing 19 kg each shall be provided at 300 mm vertically in channel of manhole.

5A.7.15.11 Frame and Covers

Frame and covers for manholes shall be of required type and dimensions as per the relevant drawings prepared by the Contractor. Following information shall be clearly marked on each cover.

Year of manufacture,

Identification mark of the purchaser,

SEWERS/SWD,

Arrow showing direction of flow

Cast Iron Frame and Cover

The cast iron frame and cover shall be of grey cast iron as per IS : 1726. The general requirements for casting and coating of CI frame and cover shall be as specified for CI steps in Clause 7.15.10. The covers shall have a raised chequered design to provide an adequate non-slip grip. The rise of the chequer shall be not less than 4 mm. The locking device for the cover shall be provided as approved by the Employer's Representative. The CI covers for the load test shall be selected at one for every lot of fifty or part thereof for each type and size manufactured and as approved by the Employer's Representative. The frame shall be fixed in cement concrete of M15 grade all round and finished with neat cement. The manhole frame shall have 560 mm diameter clear opening and shall weigh not less than 208 kg. including cover. In case of rectangular CI frame and cover of 900 mm x 600 mm clear opening, the total weight shall not be less than 275 kg. In case of scraper manhole the frame shall have clear opening of 1200 mm x 900 mm and shall weigh not less than 900 kg including cover. The manhole cover and frame shall be painted with three coats of anti-corrosive paint after fixing in position.

Fibre Reinforced Concrete Frame and Cover

Fibre reinforced concrete frame and cover shall be capable of withstanding load of 35 tonnes. The frame shall be fixed in cement concrete of M15 grade all around and finished with neat cement. The fibre reinforced frame shall have clear opening of 560 mm diameter and weighing 102 kg. The cover shall have a minimum thickness of 100 mm and weighing 78 kg. The fibres shall constitute 1% of the weight of the concrete in the form of 50 mm to 100 mm long high tensile steel wires. For the cover, MS sheet lapping of 18 gauge shall be provided to avoid damage to the edges. Similarly for frame, MS angle/flat shall be provided along the edge. Both MS sheet and angle shall be painted with black bituminous paint. The cover should have suitable lifting arrangement. The fibre reinforced frame and cover shall be manufactured as approved.

Reinforced Cement Concrete Frame and Cover

Reinforced cement concrete frame and cover for manholes shall be of required dimensions and shape as shown on the drawing prepared by the Contractor. The frame and cover shall be cast in cement concrete of M25 grade. Minimum cover to the reinforcement shall be 40 mm. The edges of frame and covers shall be provided with mild steel angles to avoid damages to the corners. These angles shall be painted with black bituminous paint. The covers should have suitable lifting arrangement.

5A.7.15.12 Drop Manhole

When a sewer connects a main sewer, and where the difference in level between water line (peak flow levels) of main line and the invert level of branch lines is more than 600 mm or a drop of more than 600 mm is required to be given in the same sewer line and it is uneconomical or impractical to arrange the connection within 600 mm, a drop connection shall be provided for which a manhole shall be constructed as per relevant drawing, incorporating a vertical drop pipe from the higher sewer to the lower one. This pipe shall be provided outside the shaft and encased in concrete. A continuation of the branch sewer should be built through the shaft wall to form a rodding and inspection eye, which should be provided with a half blank flange. The diameter of the back drop should be at least as large as that of the incoming pipe. The drop pipe should terminate at its lower end with a plain or duck-foot bend turned so as to discharge its flow at 45 degrees or less to the direction of the flow in the main sewer. The pipe unless of cast iron should be surrounded with 150 mm thick concrete.

In the case of sewers over 450 mm in diameter the drop in level may be accomplished by one of the following approved methods:

(a) A cascade;

(b) A ramp;

(c) By drops in previous manholes.

5A.7.15.13 RCC Manhole

M25 grade of concrete used for construction of RCC manhole shall have minimum cement content of 360 kg/cum of concrete. Minimum cover to the reinforcement shall be 50 mm.

5A.7.15.14 Vent Shafts

General

Vent shafts shall be erected at such places as approved by the Employer's Representative.

Mild Steel Vent Shaft

Mild steel vent shaft shall be of 150 mm diameter and 12.17 m height from ground level with C.I. ornamental cap. This shall be fixed firmly and encased in cement concrete of M15 grade as shown on relevant drawing with necessary mild steel bolts, plates etc. for foundation. The vent shaft shall be painted with one coat of silver paint over one coat of red lead oxide paint. The vent shaft shall be connected to manhole by 150 mm diameter glazed stoneware pipe encased by M10 concrete of 150 mm thickness all around as approved by the Employer's Representative.

RCC Vent Shaft

Reinforced cement concrete vent shaft shall be of M25 grade concrete, 200 mm diameter at bottom and tapered to 100 mm diameter at top (both inside clear openings) and 6 m height from ground level. The vent shaft shall be embedded in concrete of M10 grade and anchored by 2 nos. of 16 mm diameter and 600 mm long MS bars. The vent shaft shall be connected to manhole as specified in (b) above through a brick masonry flue chamber.

5A.7.15.15 Miscellaneous

If any damage is caused to the other services such as water supply pipeline, sewer, cable, etc. during the construction of manholes and erection of vent shafts, the Contractor shall be held responsible for the same and shall replace the damaged services to the full satisfaction of the Employer's Representative. The interior of manholes shall be cleared of all debris after construction and before testing the same for water tightness by the Contractor.

5A.7.16. Measurement for Pipes

AC, Cast iron and S.W. drainage pipes shall be measured along the centrelines of pipes including all fittings such as junctions, plug bends etc., for which no separate payment shall be made.

GI pipes with fittings completely fixed in position shall be measured and paid for the finished centreline lengths, including all fittings such as tees, bends, couplings etc., for which no separate payment shall be made.

In measuring the lengths of sewer pipes laid, length between faces of manholes shall be considered. Inspection chambers shall only be measured omitting lengths of channels between inside faces of walls of manholes of chambers.

Chapter – 5A.8

5A.8 - GENERAL CIVIL WORKS

5A.8.1. Applicable Codes and Specifications

The following codes and standards are included in this section.

IS:110 - Ready mixed paint, brushing, grey filler, for enamels for use over primers

IS:269 - Specification for 33 grade ordinary Portland cement

IS:280 - Specification for mild steel wire for general engineering purposes

IS:287 - Recommendations for maximum permissible moisture content of timber used for different purposes

IS : 304 - High Tensile Brass Ingots and Castings.

IS:337 - Varnish, finishing interior

IS:348 - French polish

IS:383 - Specification for coarse and fine aggregates from natural sources for concrete

IS:412 - Expanded metal steel sheets for general purposes

IS:419 - Specification for putty for use on window frames

IS:428 - Distemper, oil emulsion, colour as required

IS:459 - Specification for unreinforced corrugated and semi-corrugated asbestos cement sheets

IS:702 - Specification for industrial bitumen

IS:710 - Specification for marine plywood

IS:712 - Specification for building limes

IS:730 - Specification for hook bolts for corrugated sheet roofing

IS:733 - Wrought aluminium and aluminium alloys, bars, rods and sections for general engineering purposes

IS:1038 - Specification for steel doors, windows and ventilators

IS:1077 - Specification for common burnt clay building bricks

IS:1081 - Code of practice for fixing and glazing of metal (steel & aluminium) doors, windows and ventilators

IS:1124 - Method of test for determination of water absorption, apparent specific gravity and porosity of natural building stones

IS:1237 - Specification for cement concrete flooring tiles

IS:1322 - Bitumen felts for water proofing and damp proofing

IS:1346 - Code of practice for water proofing of roofs with bitumen felts

IS:1397 - Specification for kraft paper

IS:1443 - Code of practice for laying and finishing of cement concrete flooring tiles

IS:1477 - Code of practice for painting of ferrous metals in buildings (Parts 1 & 2)

IS:1542 - Specification for sand for plaster

IS:1580 - Specification for bituminous compounds for water-proofing and caulking purposes

IS:1597 - Code of practice for construction of stone masonry : Part 1 Rubble stone masonry

IS:1659 - Specification for block boards

IS:1661 - Code of practice for application of cement and cement-lime plaster finishes

IS:1834 - Specification for hot applied sealing compound for joint in concrete

IS:1838 - Specification for preformed fillers for expansion joint in concrete pavements and structures (non extruding and resilient type) : Part 1 Bitumen impregnated fibre

IS:1948 - Specification for aluminium doors, windows and ventilators

IS:1949 - Specification for aluminium windows for industrial buildings

IS:2074 - Ready mixed paint, air drying, red oxide- zinc chrome, priming

IS:2098 - Asbestos cement building boards

IS:2114 - Code of practice for laying in-situ terrazzo floor finish

IS:2116 - Specification for sand for masonry mortars

IS:2185 - Specification for concrete masonry units (Parts 1,2 & 3)

IS:2202 - Specification for wooden flush door shutters (Solid core type) : Parts 1 & 2

IS:2212 - Code of practice for brickwork

IS:2250 - Code of practice for preparation and use of masonry mortars

IS:2338 - Code of practice for finishing of wood and wood based materials (Parts 1 & 2)

IS:2339 - Aluminium paint for general purposes, in dual container

IS:2395 - Code of practice for painting concrete, masonry and plaster surfaces (Parts 1 & 2)

IS:2402 - Code of practice for external rendered finishes

IS:2571 - Code of practice for laying in-situ cement concrete flooring

IS:2572 - Code of practice for construction of hollow concrete block masonry

IS:2645 - Specification of integral cement waterproofing compounds

IS:2690 - Specification for burnt clay flat terracing tiles : Part 1 Machine made

IS:2691 - Specification for burnt clay facing bricks

IS:2750 - Specification for steel scaffoldings

IS:2835 - Flat transparent sheet glass

IS:2932 - Specification for enamel, synthetic, exterior type (a) undercoating, (b) finishing

IS:3007 - Code of practice for laying of asbestos cement sheets - corrugated and (Part 1 & 2) semi-corrugated sheets

IS:3036 - Code of practice for laying lime concrete for a water-proofed roof finish

IS:3067 - Code of practice of general design details and preparatory work for damp-proofing and water- proofing of buildings

IS:3068 - Specification for broken brick (burnt clay) coarse aggregates for use in lime concrete

IS:3384 - Specification for bitumen primer for use in water-proofing and damp-proofing

IS:3461 - Specification for PVC-asbestos floor tiles

IS:3462 - Specification for unpacked flexible PVC flooring

IS:3495 - Method of test for burnt clay building bricks: Part 1 to 4

IS:3536	-	Specification for ready mixed paint, brushing, wood primer, pink
IS:3564	-	Specification for door closers (hydraulically regulated)
IS: 3614 (Part – 1)	-	Specification for fire checks doors : Part –I Plate metal covered and rolling type
IS: 3614 (Part – 2)	-	Specification for metallic and non-metallic fire check doors : Part-2 Resistance test and performance criteria
IS:3696	-	Safety code of scaffolds and ladders (Parts 1 & 2)
IS:4020	-	Methods of test for wooden flush door : Type test
IS:4021	-	Specification for timber door, window and ventilator frames
IS:4351	-	Specification for steel door frames
IS:4443	-	Code of practice for use of resin type chemical resistant mortars
IS:4457	-	Specification for ceramic unglazed vitreous acid resisting tile
IS:4631	-	Code of practice for laying epoxy resin floor toppings
IS:4832	-	Specification for chemical resistant mortars (Part II)
IS:4860	-	Specification for acid resistant bricks
IS:4948	-	Specification for welded steel wire fabric for general use
IS:5318	-	Code of practice for laying of flexible PVC sheet and tile flooring
IS:5410	-	Cement paint, colour as required
IS:5411	-	Specification for plastic emulsion paint (Parts 1 & 2)
IS:5437	-	Wired and figured glass
IS:5491	-	Code of practice for laying of in-situ granolithic concrete floor topping
IS:6041	-	Code of practice construction of autoclaved cellular concrete block masonry
IS:6042	-	Code of practice for construction of light weight concrete block masonry
IS:6248	-	Specification for metal rolling shutters and rolling grilles
IS:7193	-	Specification for glass fibre base coal tar pitch and bitumen felts
IS:7452	-	Specification for hot rolled steel sections for doors, windows and ventilators
IS:8042	-	Specification for white Portland cement
IS:8543	-	Methods of testing plastics
IS:8869	-	Specification for washers for corrugated sheet roofing
IS: 9197	-	Specification for epoxy resin, hardeners and epoxy resin composites for floor topping
IS:9862	-	Specification for ready mixed paint, brushing, bituminous, black, lead-free, acid, alkali, water and chlorine resisting
IS:12200	-	Code of practice for provision of waterstops at transverse contraction joints in masonry and concrete dams
BS : 476 (Part – 20)	-	Methods for determination of the fire resistance of elements of construction (General Principles)
BS : 476 (Part – 21)	-	Methods for determination of the fire resistance of load bearing elements of construction

BS : 476 (Part – 22)	-	Methods for determination of the fire resistance of non-load bearing elements of construction
Part – IV	-	National Building code of India (Fire Protection)

5A.8.2. Brickwork

5A.8.2.1 Materials

Bricks used in the works shall conform to the requirements laid down in IS: 1077. The class of the bricks shall be as specifically indicated in the respective items of work.

The nominal size of the modular brick shall be 200mmx100mmx100mm with the permissible tolerances over the actual size of 190mmx90mmx90mm as per IS: 1077. The nominal thickness of one brick and half brick walls using modular bricks shall be considered as 200 mm and 100 mm respectively. In the event of use of traditional bricks of nominal size 230 mmx115mmx75mm with tolerance upto ±3 mm in each dimension, one brick and half brick walls shall be considered as 230 mm and 115 mm respectively.

Bricks shall be sound, hard, homogenous in texture, well burnt in kiln without being vitrified, hand/machine moulded, deep red, cherry or copper coloured, of regular shape and size & shall have sharp and square edges with smooth rectangular faces. The bricks shall be free from pores, cracks, flaws and nodules of free lime. Hand moulded bricks shall be moulded with a frog and those made by extrusion process may not be provided with a frog. Bricks shall give a clear ringing sound when struck and shall have a minimum crushing strength of 5N/sq.mm unless otherwise specified in the items of work.

The average water absorption shall not be more than 20 percent by weight upto class 12.5 and 15 percent by weight for higher classes. Bricks which do not conform to this requirement shall be rejected. Over or under burnt bricks are not acceptable for use in the works.

Sample bricks shall be submitted to the Engineer for approval and bricks supplied shall conform to approved samples. If demanded by Engineer, brick samples shall be got tested as per IS: 3495 by Contractor. Bricks rejected by Engineer shall be removed from the site of works within 24 hours.

Mortar for brick masonry shall consist of cement and sand and shall be prepared as per IS: 2250. Mix shall be in the proportion of 1:5 for brickwork of thickness one brick or above and 1:4 for brickwork of thickness half brick or below, unless otherwise specified in the respective items of work. Sand for masonry mortar shall conform to IS: 2116. The sand shall be free from clay, shale, loam, alkali and organic matter and shall be of sound, hard, clean and durable particles. Sand shall be approved by Engineer. If so directed by the Engineer, sand shall be screened and washed till it satisfies the limits of deleterious materials.

For preparing cement mortar, the ingredients shall first be mixed thoroughly in dry condition. Water shall then be added and mixing continued to give a uniform mix of required consistency. Mixing shall be done thoroughly in a mechanical mixer, unless hand mixing is specifically permitted by the Engineer. The mortar thus mixed shall be used as soon as possible, preferably within 30 minutes from the time water is added to cement. Incase, the mortar has stiffened due to evaporation of water, this may be re-tempered by adding water as required to restore consistency, but this will be permitted only upto 30 minutes from the time of initial mixing of water to cement. Any mortar which is partially set shall be rejected and shall be removed forthwith from the site. Droppings of mortar shall not be re-used under any circumstances.

The Contractor shall arrange for test on mortar samples if so directed by the Engineer.

5A.8.2.2 Workmanship

Workmanship of brick work shall conform to IS: 2212. All bricks shall be thoroughly soaked in clean water for at least one hour immediately before being laid. The cement mortar for brick masonry work shall be as specified in the respective item of work. Brick work 200mm/230mm thick and over shall be laid in English Bond unless otherwise specified. 100mm/115mm thick brickwork shall be laid with stretchers. For laying bricks, a layer of mortar shall be spread over the full width of suitable length of the lower course. Each brick shall be slightly pressed into the mortar and shoved into final position so as to embed the brick fully in mortar. Only full size bricks shall be used for the works and cut bricks utilised only to make up required wall length or for bonding. Bricks shall be laid with frogs uppermost.

All brickwork shall be plumb, square and true to dimensions shown. Vertical joints in alternate courses shall come directly one over the other and be in line. Horizontal courses shall be levelled. The thickness of brick courses shall be kept uniform. In case of one brick thick or half brick thick wall, atleast one face should be kept smooth and plane, even if the other is slightly rough due to variation in size of bricks. For walls of thickness greater than one brick both faces shall be kept smooth and plane. All interconnected brickwork shall be carried out at nearly one level so that there is uniform distribution of pressure on the supporting structure and no portion of the work shall be left more than one course lower than the adjacent work. Where this is not possible, the work shall be raked back according to bond (and not saw toothed) at an angle not exceeding 45 deg. But in no case the level difference between adjoining walls shall exceed one metre. Brick work shall not be raised more than one metre per day.

Bricks shall be so laid that all joints are well filled with mortar. The thickness of joints shall not be less than 6 mm and not more than 10 mm. The face joints shall be raked to a minimum depth of 10mm/15mm by raking tools during the progress of work when the mortar is still green, so as to provide a proper key for the plastering/ pointing respectively to be done later. When plastering or pointing is not required to be done, the joints shall be uniform in thickness and be struck flush and finished at the time of laying. The face of brickwork shall be cleaned daily and all mortar droppings removed. The surface of each course shall be thoroughly cleaned of all dirt before another course is laid on top.

During inclement weather conditions, newly built brick masonry works shall be protected by tarpaulin or other suitable covering to prevent mortar being washed away by rain.

Brickwork shall be kept constantly moist on all the faces for at least seven days after 24 hrs of laying. The arrangement for curing shall be got approved from the Engineer.

Double scaffolding having two sets of vertical supports shall be provided to facilitate execution of the masonry works. The scaffolding shall be designed adequately considering all the dead, live and possible impact loads to ensure safety of the workmen, in accordance with the requirements stipulated in IS:2750 and IS:3696 (Part I). Scaffolding shall be properly maintained during the entire period of construction. Single scaffolding shall not be used on important works and will be permitted only in certain cases as decided by the Engineer. Where single scaffolding is adopted, only minimum number of holes, by omitting a header shall be left in the masonry for supporting horizontal scaffolding poles. All holes in the masonry shall be carefully made good before plastering/pointing.

In the event of usage of traditional bricks of size 230 mm x115mm x75mm, the courses at the top of the plinth and sills as well as at the top of the wall just below the roof/floor slabs and at the top of the parapet shall be laid with bricks on edge.

All brickwork shall be built tightly against columns, floor slabs or other structural members.

To overcome the possibility of development of cracks in the brick masonry following measures shall be adopted.

For resting RCC slabs, the bearing surface of masonry wall shall be finished on top with 12 mm thick cement mortar 1:3 and provided with 2 layers of Kraft paper Grade 1 as per IS:1397 or 2 layers of 50 micron thick polyethylene sheets.

RCC/ steel beams resting on masonry wall shall be provided with reinforced concrete bed blocks of 50 mm thickness, projecting 50mm on either sides of the beam, duly finished on top with 2 layers of Kraft paper Grade 1 as per IS:1397 or 2 layers of 50 micron thick polyethylene sheets.

Steel wire fabric shall be provided at the junction of brick masonry and concrete before taking up plastering work.

Bricks for partition walls shall be stacked adjacent to the structural member to pre-deflect the structural member before the wall is taken up for execution. Further, the top most course of half or full brick walls abutting against either a de-shuttered slab or beam shall be built only after any proposed masonry wall above the structural member is executed to cater for the deflection of the structural element.

Reinforced cement concrete transoms and mullions of dimensions as indicated in the construction Drawings are generally required to be provided in the half brick partition walls.

Where the drawings indicate that structural steel sections are to be encased in brickwork, the brick masonry shall be built closely against the steel section, ensuring a minimum of 20 mm thick cement-sand mortar 1:4 over all the steel surfaces. Steel sections partly embedded in brickwork shall be provided with bituminous protective coating to the surfaces at the point of entry into the brick masonry.

Contractor shall note that the unit rates quoted for the masonry work shall be deemed to include for the installation of miscellaneous inserts such as pipe sleeves, bolts, steel sections with anchors etc. and provide pockets, leaving openings, cutting chases etc. in accordance with the construction drawings. Miscellaneous inserts shall be either supplied free by the Employer or to be furnished by the Contractor. Any of the miscellaneous inserts which are required to be fabricated and supplied by the

Contractor and cement concrete to be provided in the pockets for holdfasts of door/window frames etc. shall however, be measured and paid for separately under the respective items of work.

Facing bricks of the type specified conforming to IS: 2691 shall be laid in the positions indicated on the drawings and all facing brickwork shall be well bonded to the backing bricks/RCC surfaces. The level of execution of the facing brick work shall at any time be lower by at least 600 mm below the level of the backing brickwork.

Facing bricks shall be laid over 10 mm thick backing of cement mortar. The mortar mix, thickness of joint and the type of pointing to be carried out shall be as specified in the item of works. The pattern of laying the bricks shall be as specifically indicated in the drawings.

For facing brickwork, double scaffolding shall be used.

Faced works shall be kept clean and free from damage, discoloration etc., at all times.

5A.8.3. Uncoursed Random Rubble Masonry in Foundation, Plinth and Superstructure

5A.8.3.1 Materials

Stones for the works shall be of the specified variety which is hard, durable, fine grained and uniform in colour (for superstructure work) free from veins, flaws and other defects. Quality and work shall conform to the requirements specified in IS:1597 (Part-I). The percentage of water absorption shall not exceed 5 percent as per test conducted in accordance with IS: 1124. The Contractor shall supply sample stones to the Engineer for approval. Stones shall be laid with its grains horizontal so that the load transmitted is always perpendicular to the natural bed.

Cement-sand mortar for stone masonry works shall be in the proportion of 1:6. Materials and preparation of mortar shall be as specified in clause 8.2.1.

5A.8.3.2 Workmanship

For all works below ground level the masonry shall be random rubble uncoursed with ordinary quarry dressed stones for the hearting and selected quarry dressed stones for the facing.

For all works above ground level and in superstructure the masonry shall be random rubble uncoursed, well bonded, faced with hammer dressed stones with squared quoins at corners. The bushings on the face shall not be more than 40 mm on an exposed face and on the face to be plastered it shall not project by more than 12 mm nor shall it have depressions more than 10 mm from the average wall surface.

Face stones shall extend back sufficiently and bond well with the masonry. The depth of stone from the face of the wall inwards shall not be less than the height or breadth at the face. The length of the stone shall not exceed three times the height and the breadth on base shall not be greater than three-fourths the thickness of wall nor less than 150 mm. The height of stone may be up to a maximum of 300 mm. Face stones or hearting stones shall not be less than 150 mm in any direction.

Chips and spalls shall be used wherever necessary to avoid thick mortar joints and to ensure that no hollow spaces are left in the masonry. The use of chips and spalls in the hearting shall not exceed 20 percent of the quantity of stone masonry. Spalls and chips shall not be used on the face of the wall and below hearting stones to bring them to the level of face stones.

The maximum thickness of joints shall not exceed 20 mm. All joints shall be completely filled with mortar. When plastering or pointing is not required to be done, the joints shall be struck flush and finished as the work proceeds. Otherwise, the joints shall be raked to a minimum depth of 20 mm by a raking tool during the progress of the work while the mortar is still green.

Through or bond stones shall be provided in walls up to 600 mm thick and in case of walls above 600 mm thickness, a set of two or more bond stones overlapping each other by at least 150 mm shall be provided in a line from face to back. In case of highly absorbent types of stones (porous lime stone and sand stone, etc.) the bond stone shall extend about two-thirds into the wall and a set of two or more bond stones overlapping each other by at least 150 mm shall be provided. Each bond stone or a set of bond stones shall be provided for every 0.5 sq. m of wall surface.

All stones shall be sufficiently wetted before laying to prevent absorption of water from the mortar. All connected walls in a structure shall be normally raised uniformly and regularly. However if any part of the masonry is required to be left behind, the wall shall be raked back (and not saw toothed) at an angle not exceeding 45deg. Masonry work shall not be raised by more than one metre per day.

Green work shall be protected from rain by suitable covering. Masonry work shall be kept constantly moist on all the faces for a minimum period of seven days for proper curing of the joints.

Type of scaffolding to be used shall be as specified in clause 8.2.2.

5A.8.4. Coursed Rubble Masonry (First Sort) for Superstructure

5A.8.4.1 Materials

The Material specification for the work shall be as per clause 8.3.1.

5A.8.4.2 Workmanship

All courses shall be laid truly horizontal and shall be of the same height in any course. The height of course shall not be less than 150 mm and not more than 300 mm. The width of stone shall not be less than its height.

Face stones shall tail into the work for not less than their height and at least 1/3rd the number of stones shall tail into the work for a length not less than twice their height but not more than three-fourths the thickness of the wall whichever is smaller. These should be laid as headers and stretchers alternately to break joints by at least 75 mm.

The face stones shall be squared on all joints and beds; the bed joints being hammer or chisel dressed true and square for at least 80 mm back from the face and the side joints for at least 40 mm. The face of the stone shall be hammer dressed so that the bushing shall not be more than 40 mm on an exposed face and 10 mm on a face to be plastered. No portion of the dressed surface shall show a depth of gap more than 6 mm from a straight edge placed on it. The remaining unexposed portion of the stone shall not project beyond the surface of bed and side joints.

No spalls or pinnings shall be allowed on the face. All bed joints shall be horizontal and side joints shall be vertical and no joints shall be more than 10 mm in thickness. When plastering or pointing is not required to be done, the joints shall be struck flush and finished as the work proceeds. Otherwise, the joints shall be raked to a minimum depth of 20 mm by a raking tool, during the progress of the work while the mortar is still green.

Hearting shall consist of flat bedded stones carefully laid on their proper beds and solidly bedded in mortar. The use of chips shall be restricted to the filling of interstices between the adjacent stones in hearting and these shall not exceed 10 percent of the quantity of the stone masonry. Care shall be taken so that no hollow spaces are left anywhere in the masonry.

The requirement regarding through or bond stones shall be as specified in clause 8.3.2 with the further stipulation that these shall be provided at 1.5 m to 1.8m apart clear in every course but staggered at alternate courses.

The quoins which shall be of the same height as the course in which they occur, shall not be less than 450 mm in any direction. Quoin stones shall be laid as stretchers and headers alternately. They shall be laid square on their beds, which shall be rough chisel dressed to a depth of at least 100 mm from the face. These stones shall have minimum uniform chisel drafts of 25mm width at four edges, all the edges being in the same plane.

Type of scaffolding to be used shall be as per Clause 8.2.2.

Requirements of execution of the work and curing shall be as stipulated in clause 8.3.2 .

5A.8.5. Concrete Block Masonry

5A.8.5.1 Materials

Masonry units of hollow and solid concrete blocks shall conform to the requirements of IS : 2185 (Part 1). Masonry units of hollow and solid light-weight concrete blocks shall conform to the requirements of IS : 2185 (Part 2).

Masonry units of autoclaved cellular concrete blocks shall conform to the requirements of IS:2185 (Part 3).

The height of the concrete masonry units shall not exceed either its length or six times its width.

The nominal dimensions of concrete block shall be as under.

Length 400, 500 or 600 mm

Height 100 or 200 mm

Width 100 to 300 mm in 50 mm increments

Half blocks shall be in lengths of 200, 250 or 300mm to correspond to the full length blocks. Actual dimensions shall be 10mm short of the nominal dimensions.

The maximum variation in the length of the units shall not be more than ±5 mm and maximum variation in height or width of the units shall not be more than ± 3mm.

Concrete blocks shall be either hollow blocks with open or closed cavities or solid blocks.

Concrete blocks shall be sound, free of cracks, chipping or other defects which impair the strength or performance of the construction. Surface texture shall as specified. The faces of the units shall be flat and rectangular, opposite faces shall be parallel and all arises shall be square. The bedding surfaces shall be at right angles to the faces of the block.

The concrete mix for the hollow and solid concrete blocks/light weight concrete blocks shall not be richer than one part of cement to six parts of combined aggregates by volume.

Concrete blocks shall be of approved manufacture, which satisfy the limitations in the values of water absorption, drying shrinkage and moisture movement, as specified for the type of block as per relevant IS code. Contractor shall furnish the test certificates and also supply the samples for the approval of Engineer.

5A.8.5.2 Workmanship

The type of the concrete block, thickness and grade based on the compressive strength for use in load bearing and/or non-load bearing walls shall be as specified. The minimum nominal thickness of non-load bearing internal walls shall be 100mm. The minimum nominal thickness of external panel walls in framed construction shall be 200 mm.

The workmanship shall generally conform to the requirements of IS: 2572 for concrete block masonry, IS:6042 for light weight concrete block masonry and IS:6041 for autoclaved cellular concrete block masonry works.

From considerations of durability, generally concrete block masonry shall be used in superstructure works above the damp-proof course level.

Concrete blocks shall be embedded with a mortar which is relatively weaker than the mix of the blocks in order to avoid the formation of cracks. Cement mortar of proportion 1:6 shall be used for the works. Preparation of mortar shall be as specified in clause 8.2.1.

The thickness of both horizontal and vertical joints shall be 10mm. The first course shall be laid with greater care, ensuring that it is properly aligned, leveled and plumb since this will facilitate in laying succeeding courses to obtain a straight and truly vertical wall. For the horizontal (bedding) joint, mortar shall be spread over the entire top surface of the block including front and rear shells as well as the webs to a uniform layer of 10mm. For vertical joints, the mortar shall be applied on the vertical edges of the front and rear shells of the blocks. The mortar may be applied either to the unit already placed on the wall or on the edges of the succeeding unit when it is standing vertically and then placing it horizontally, well pressed against the previously laid unit to produce a compacted vertical joint. In case of two cell blocks with slight depression on the vertical sides these shall also be filled up with mortar to secure greater lateral rigidity. To assure satisfactory bond, mortar shall not be spread too far ahead of actual laying of the block as the mortar will stiffen and lose its plasticity Mortar while hardening shrinks slightly and thus pulls away from the edges of the block. The mortar shall be pressed against the units with a jointing tool after it has stiffened to effect intimate contact between the mortar and the unit to obtain a weather tight joint. The mortar shall be raked to a depth of 10mm as each course is laid to ensure good bond for the plaster.

Dimensional stability of hollow concrete blocks is greatly affected by variations of moisture content in the units. Only well dried blocks should be used for the construction. Blocks with moisture content more than 25% of maximum water absorption permissible shall not be used. The blocks should not be wetted before or during laying in the walls. Blocks should be laid dry except slightly moistening their surfaces on which mortar is to be applied to obviate absorption of water from the mortar.

As per the design requirements and to effectively control cracks in the masonry, RCC bound beams/studs, joint reinforcement shall be provided at suitable locations. Joint reinforcement shall be fabricated either from mild steel wires conforming to IS:280 or welded wire fabric/high strength deformed basis as per the drawings.

For jambs of doors, windows and openings, solid concrete blocks shall be provided. If hollow units are used, the hollows shall be filled with concrete of mix 1:3:6. Hold fasts of doors/windows should be arranged so that they occur at block course level.

At intersection of walls, the courses shall laid up at the same time with a true masonry bond between atleast 50% of the concrete blocks. The sequence for construction of partition walls and treatment at the top of load bearing walls for the RCC slab shall be as detailed under clause 8.2 for the brick work.

Curing of the mortar joints shall be carried out for atleast 7 days. The walls should only be lightly moistened and shall not be allowed to become excessively wet.

Double scaffolding as per clause 8.2.2 shall be adopted for execution of block masonry work.

Cutting of the units shall be restricted to a minimum. All horizontal and vertical dimensions shall be in respectively, adopting modular co-ordination for walls, opening locations for doors, windows etc.

Concrete blocks shall be stored at site suitably to avoid any contact with moisture from the ground and covered to protect against wetting.

5A.8.6. Damp - Proof Course

5A.8.6.1 Materials and Workmanship

Where specified, all the walls in a building shall be provided with damp-proof course cover plinth to prevent water from rising up the wall. The damp-proof course shall run without a break throughout the length of the wall, even under the door or other openings. Damp-proof course shall consist of 50 mm thick cement concrete of 1:2:4 nominal mix with approved water-proofing compound admixture conforming to IS: 2645 in proportion as directed by the manufacturer. Concrete shall be with 10 mm down graded coarse aggregates.

The surface of brick work/stone masonry work shall be leveled and prepared before laying the cement concrete. Side shuttering shall be properly fixed to ensure that slurry does not leak through and is also not disturbed during compaction. The upper and side surface shall be made rough to afford key to the masonry above and to the plaster.

Damp-proof course shall be cured properly for atleast seven days after which it shall be allowed to dry for taking up further work.

5A.8.7. Miscellaneous Inserts, Bolts etc.

All the miscellaneous inserts such as bolts, pipes, plate embedment etc., shall be accurately installed in the building works at the correct location and levels, all as detailed in the construction drawings. Contractor shall prepare and use templates for this purpose, if so directed by the Engineer. In the event, of any of the inserts are improperly installed, Contractor shall make necessary arrangements to remove and reinstall at the correct locations/levels, all as directed by the Engineer without any extra cost to the Employer.

5A.8.8. Wood Work in Doors, Windows, Ventilators & Partitions

5A.8.8.1 Materials

Timber to be used shall be first class Teak wood as per IS:4021. Timber shall be of the best quality and well-seasoned by a suitable process before being planned to the required sizes. The maximum permissible moisture content shall be from 10 to 16 percent for timber 50mm and above in thickness and 8 to 14 percent of timber less than 50mm in thickness for different regions of the country as stipulated in IS:287. Timber shall be close grained, of uniform colour and free from decay, fungal growth, boxed heart, pitch pockets or streaks on the exposed edges, borer holes, splits and cracks.

Flush door shutters of the solid core type with plywood face panels shall conform to IS: 2202 (Part 1) and with particle board/hard board face panels shall conform to IS: 2202 (Part 2).

Transparent sheet glass shall conform to the requirements of IS: 2835. Wired and figured glass shall be as per IS: 5437.

Builder’s hardware for fittings and fixtures shall be of the best quality from approved manufacturers.

5A.8.8.2 Workmanship

The workmanship and finish of wood work in doors, windows, ventilators and partitions shall be of a very high order. Contractor shall ensure that work is executed in a professional manner by skilled carpenters for good appearance, efficient and smooth operation of the shutters.

All works shall be executed as per the detailed drawings and/or as directed by the Engineer.

All members of the door, window, and ventilator shall be straight without any warp or bow and shall have smooth well planed faces. The right angle shall be checked from the inside surfaces of the respective members of the frame. Frames shall have mortice and tenon joints which shall be treated with an approved adhesive and provided with metal or wood pins. The vertical members of the door frame shall project 50 mm below the finished floor level. The finished dimension of frames shall be rebated on the solid for keying with the plaster and for receiving the shutters. The depth of rebate for housing the shutter shall be 15 mm. The size of the frames shall be as specified in the respective items of work. The workmanship shall generally conform to the requirements specified in IS:4021.

The face of the frames abutting the masonry or concrete shall be provided with a coat of coal tar.

Three hold fasts using 25 mm x 6 mm mild steel flats 225 mm long with split ends shall be fixed on each side of door and window frames, one at the centre and the other two at 300 mm from the top and bottom of the frame. For window and ventilator frames less than 1 m in height, two hold fasts on each side shall be fixed at quarter points.

Timber panelled shutters for doors, windows and ventilators shall be constructed in the form of framework of stiles and rails with panel insertion. The panels shall be fixed by either providing grooves in the stiles and rails or by beading. Glazing bars shall be as detailed in the drawings. The stiles and rails shall be joined by mortice and tenon joints at right angles. All members of the shutter shall be straight without any warp or bow and shall have smooth, well planed faces at right angles to each other. The right angle for the shutter shall be checked by measuring the diagonals and the difference shall not be more than ± 3 mm. Timber panels made from more than one piece shall be jointed with a continuous tongued and grooved joint, glued together and reinforced with metal dowels. The workmanship shall generally conform to the requirements specified in IS: 1003 (Parts 1 & 2). The thickness of the shutter, width/thickness of the stiles/rails/panel type shall be as specified. Marine plywood panels conforming to IS: 710 shall be used for doors where specified.

Details of the wooden flush door shutters, solid core type with specific requirement of the thickness, core, face panels, viewing glazed panel, venetian louvre opening, teak wood lipping etc. shall be as specified. Panels of shutter shall be of marine plywood conforming to IS: 710. Flush door shutters shall be from reputed manufacturers and Contractor shall submit test results as per IS: 4020, if so desired by the Engineer.

Glazing of door, window, ventilator and partitions shall be with either flat transparent sheet glass, wired or figured glass. Transparent sheet glass shall be of 'B' quality as per IS: 2835.The thickness and type of glazing to be provided shall be as specified in the item of work.

The material of the fittings and fixtures either of chromium plated steel, cast brass, copper oxidised or anodised aluminium shall be as specified. The number, size and type of the fittings and fixtures shall be as indicated in the drawings/item of work.

Wood work shall not be provided with the finishes of painting/varnishing etc. unless it has been approved by the Engineer. The type of finish and the number of coats shall be as stipulated in the respective items of work.

Wooden hand railing and architraves shall be of the size and shape with the fixing arrangement as indicated in the drawings.

The framework of the partitions with mullions and transomes shall be with the sections of dimensions as specified. Panels of double/single glazing/plywood shall be fixed as per details specified. Partitions shall be fixed rigidly between the floor and structural columns/beams including provision of necessary shims for wedging etc. Finished work shall be of rigid construction, erected truly plumb to the lines and levels, at locations as per the Construction drawings.

Any carpentry work which shows defects due to inadequate seasoning of the timber or bad workmanship shall be removed and replaced by Contractor with work as per Specifications at no extra cost to the Employer.

5A.8.9. Steel Doors, Windows and Ventilators

5A.8.9.1 Materials

Hot rolled steel sections for the fabrication of steel doors, windows and ventilators shall conform to IS: 7452 which are suitable for single glazing .

Pressed steel door frames for steel flush doors shall be out of 1.25mm thick mild steel sheets of profiles as per IS : 4351.

Transparent sheet glass shall conform to the requirements of IS : 2835. Wired and figured glass shall be as per IS: 5437.

Builder's hardware of fittings and fixtures shall be of the best quality from the approved manufacturers.

5A.8.9.2 Workmanship

All steel doors, windows and ventilators shall be of the type as specified in the respective items of work and of sizes as indicated in the drawings. Steel doors, windows and ventilators shall conform to the requirements as stipulated in IS : 1038. Steel windows shall conform to IS : 1361, if so specified.

Doors, windows and ventilators shall be of an approved manufacture. Fabrication of the unit shall be with rolled section, cut to correct lengths and mitred. Corners shall be welded to form a solid fused welded joint conforming to the requirements of IS : 1038. Tolerance in overall dimensions shall be within ±1.5mm. The frames and shutters shall be free from wrap or buckle and shall be square and truly plain. All welds shall be dressed flush on exposed and contact surfaces. Punching of holes, slots and other provisions to install fittings and fixtures later shall be made at the correct locations as per the requirements. Samples of the units shall be got approved by the Engineer before further manufacture/purchase by the Contractor.

Type and details of shutters, hinges, glazing bar requirement, couplings, locking arrangement, fittings and fixtures shall be as described in the respective items of work and / or as shown in the drawings for single or composite units.

For windows with fly proof mesh as per the item of work, rotor operator arrangement, for the operation of the glazed shutters from the inside shall be provided.

Pressed steel door frames shall be provided with fixing lugs at each jamb, hinges, lock-strike plate, mortar guards, angle threshold, shock-absorbers of rubber or similar material as per the requirements of IS : 4351. Pressed steel door frames shall be fixed as `built-in' as the masonry work proceeds. After placing it plumb at the specified location, masonry walls shall be built up solid on either side and each course grouted with mortar to ensure solid contact with the door frame, without leaving any voids. Temporary struts across the width shall be fixed, during erection to prevent bow/sag of the frame.

Door shutters of flush welded construction shall be 45mm thick, fabricated with two outer skins of 1.25mm thick steel sheets, 1mm thick steel sheet stiffeners and steel channels on all four edges. Double shutters shall have meeting stile edge bevelled or rebated. Provision of glazed viewing panel, louvers shall be made as per the items of works and/or drawings. Shutters shall be suitably reinforced for lock and other surface hardware and to prevent sagging/twisting. Single sheet steel door shutters shall be fabricated out of 1.25mm thick steel sheets, mild steel angles and stiffeners as per the drawings.

Doors, windows and ventilators shall be fixed into the prepared openings. They shall not be 'built-in' as the masonry work proceeds, to avoid distortion and damage of the units. The dimensions of the masonry opening shall have 10mm clearance all-round the overall dimensions of the frame for this purpose. Any support of scaffolding members on the frames/glazing bars is prohibited.

Glazing of the units shall be either with flat transparent glass or wired / figured glass of the thickness as specified in the items of works. All glass panels shall have properly squared corner and straight edges. Glazing shall be provided on the outside of the frames.

Fixing of the glazing shall be either with spring glazing clips and putty conforming to IS:419 or with metal beads. Pre-formed PVC or rubber gaskets shall be provided for fixing the beads with the concealed screws. The type of fixing the glazing shall be as indicated in the items of work and/or in drawings.

Steel doors, windows and ventilators shall be provided with finish of either painting as specified or shall be hot dip galvanised with thickness of the zinc coating as stipulated all as described in the respective items of works.

The material of the Builders hardware of fittings and fixtures of chromium plated steel, cast brass, brass copper oxidised or anodised aluminium shall be as specified in the items of works. The number, size and type of fittings and fixtures shall be as in the Drawings /items of work.

Installation of the units with fixing lugs, screws, mastic caulking compound at the specified locations shall generally conform to the requirements of IS:1081. Necessary holes etc required for fixing shall be made by the Contractor and made good after installation. Workmanship expected is of a high order for efficient and smooth operation of the units.

5A.8.10. Aluminium Doors, Windows, Ventilators & Partitions

5A.8.10.1 Materials

Aluminum alloy used in the manufacture of extruded sections for the fabrication of doors, windows, ventilators shall conform to designation HE9-WP of IS:733.

Transparent sheet glass shall conform to the requirements of IS:2835. Wired and figured glass shall be as per IS:5437.

Builder's hardware of fittings & fixtures shall be of the best quality from approved manufacturers.

5A.8.10.2 Workmanship

ventilators and partitions shall be of the type and size as specified. The doors, windows, ventilators shall conform to the requirements of IS:1948. Aluminum windows, shall conform to IS:1949, if so specified.

All aluminum units shall be supplied with anodized finish. The minimum anodic film thickness shall be 0.015 mm.

Doors, windows and ventilators shall be of an approved manufacture. Fabrication of the units shall be with the extruded sections, cut to correct lengths, mitred and welded at the corners to a true right angle conforming to the requirements of IS:1948. Tolerance in overall dimensions shall be within ± 1.5mm.

The frames and shutters shall be free from warp or buckle and shall be square and truly plane. Punching of holes, slots and other provisions to install fittings or fixtures later shall be made at the correct locations, as per the requirements.

Aluminium swing type doors, aluminum sliding windows, partitions shall be as described in the items of work / drawings.

IS:1948 and IS:1949 refers to incorporating the sizes, shapes, thicknesses and weight per running metre of extruded sections for various components of the units. However, new sizes, shapes, thicknesses with modifications to suit snap-fit glazing clips etc. are continuously being added by various leading manufacturers of extruded sections, which are available in the market. As such, the sections of the various components of the unit proposed by the Contractor, will be reviewed by the Engineer and will be accepted only if they are equal to or marginally more than that given in the codes / specified in the items of work.

The framework of the partitions with mullions and transomes shall be with anodised aluminium box sections. Anodised aluminium box sections shall be in-filled with timber of class 3 (silver oak or any other equivalent) as per IS:4021. Panels of double/single glazing/plywood shall be fixed as per details indicated in the drawings. Partitions shall be fixed rigidly between the floor and the structural columns/beams including provision of necessary shims for wedging etc. Finished work shall be of rigid construction, erected truly plumb to the lines and levels, at locations as per the construction drawings.

Specific provisions as stipulated for steel doors, windows, ventilators under clause 8.9.2 shall also be applicable for this item work. Glazing beads shall be of the snap-fit type suitable for the thickness of glazing proposed as indicated in the items of works. A layer of clear transparent lacquer shall be applied on aluminium sections to protect them from damage during installation. This lacquer coating shall be removed after the installation is completed.

5A.8.11. Steel Rolling Shutters

5A.8.11.1 Materials and Workmanship

Rolling shutters shall be of an approved manufacture, conforming to the requirements specified in IS: 6248.

The type of rolling shutter shall be self coiling type (manual) for clear areas upto 12 sq.m, gear operated type (mechanical) for clear areas upto 35 sq.m and electrically operated type for areas upto 50 sq.m. Mechanical type of rolling shutters shall be suitable for operation from both inside and outside with the crank handle or chain gear operating mechanism duly considering the size of wall/column. Electrical type of rolling shutter shall also be provided with a facility for emergency mechanical operation.

Rolling shutters shall be supplied duly considering the type, specified clear width/height of the opening and the location of fixing as indicated in the drawings.

Shutters shall be built up of interlocking laths 75 mm width between rolling centres formed from cold rolled steel strips. The thickness of the steel strip shall not be less than 0.90 mm for shutters upto

3.50m width and not less than 1.20 mm for shutters above 3.50 m width. Each lath section shall be continuous single piece without any welded joint.

The guide channels out of mild steel sheets of thickness not less than 3.15 mm shall be of either rolled, pressed or built up construction. The channel shall be of size as stipulated in IS:6248 for various clear widths of the shutters.

Hood covers shall be of mild steel sheets not less than 0.90 mm thick and of approved shape.

Rolling shutters shall be provided with a central hasp and staple safety device in addition to one pair of lever locks and sliding locks at the ends.

All component parts of the steel rolling shutter (excepting springs and insides of guide channels) shall be provided with one coat of zinc chrome primer conformity to IS:2074 at the shop before supply. These surfaces shall be given an additional coat of primer after erection at the site along with the number of coats and type of finish paint as specified in the respective items of work.

In case of galvanised rolling shutter, the lath sections, guides, lock plate, bracket plates, suspension shaft and the hood cover shall be hot dip galvanised with a zinc coating containing not less than 97.5 percent pure zinc. The weight of the zinc coating per sq.m shall be as specified in the items of work.

Guide channels shall be installed truly plumb at the specified location. Bracket plate shall be rigidly fixed with necessary bolts and holdfasts. Workmanship of erection shall ensure strength and rigidity of rolling shutter for trouble free and smooth operation.

5A.8.12. Rubble Sub-Base

5A.8.12.1 Materials

Stones used for rubble packing under floors on grade, foundations etc., shall be clean, hard, durable rock free from veins, flaws, laminations, weathering and other defects. Stones shall generally conform to the requirements stipulated in IS: 1597 (Part I).

Stones shall be as regular as can be obtained from quarries. Stones shall be of height equal to the thickness of the packing proposed with a tolerance of ± 10 mm. Stones shall not have a base area neither less than 250 sq cm nor more than 500 sq.cm, and the smallest dimension of any stone shall not be less than half the largest dimension. The quality and size of stones shall be subject to the approval of the Engineer.

5A.8.12.2 Workmanship

Stones shall be hand packed carefully and laid with their largest base downwards resting flat on the prepared sub-grade and with their height equal to the thickness of the packing. Stones shall be laid breaking joints and in close contact with each other. All interstices between the stones shall be wedged-in by small stones of suitable size, well driven in by crow bars and hammers to ensure tight packing and complete filling-in of the interstices. The wedging shall be carried out simultaneously with the placing in position of rubble packing and shall not lag behind. After this, any interstices between the smaller wedged stones shall be infilled with clean hard sand by brooming so as to fill the joints completely. The laid rubble packing shall be sprinkled with water and compacted by using suitable rammers.

5A.8.13. Base Concrete

The thickness and grade of concrete and reinforcement shall be as specified in items of work.

Before placing the blinding concrete, the sub-base of rubble packing shall be properly wetted and rammed. Concrete for the base shall then be deposited between the forms, thoroughly tamped and the surface finished level with the top edges of the forms. Two or three hours after the concrete has been laid in position, the surface shall be roughened using steel wire brush to remove any scum or laitance and swept clean so that the coarse aggregates are exposed. The surface of the base concrete shall be left rough to provide adequate bond for the floor finish to be provided later.

5A.8.14. Terrazzo and Plain Cement Tiling Work

5A.8.14.1 Materials

Terrazzo tiles and cement tiles shall generally conform in all respects to standards stipulated in IS: 1237. Tiles shall be of the best quality manufactured adopting hydraulic pressure of not less than $14N/mm^2$.

The type, quality, size, thickness colour etc, of the tiles for flooring/dado/skirting shall be as specified in the items of work.

The aggregates for terrazzo topping shall consist of marble chips which are hard, sound and dense. Cement to be used shall be either ordinary Portland cement or white cement with or without colouring pigment. The binder mix shall be with 3 parts of cement to 1 part of marble powder by weight. The proportion of cement shall be inclusive of any pigments. For every one part of cement-marble powder binder mix, the proportion of aggregates shall be 1.75 parts by volume, if the chips are between 1mm to 6mm and 1.50 parts by volume if the chips are between 6mm to 25mm.

The minimum thickness of wearing layer of terrazzo tiles shall be 5mm for tiles with chips of size varying from 1mm upto 6mm or from 1mm upto 12mm. This shall be 6mm for tiles with chips varying from 1mm upto 25mm. The minimum thickness of wearing layer of cement/coloured cement tiles shall be 5mm. This shall be 6mm for heavy duty tiles. Pigment used in the wearing layer shall not exceed 10 percent of the weight of cement used in the mix.

5A.8.14.2 Workmanship

Laying and finishing of tiles shall conform to the requirements of workmanship stipulated in IS:1443.

Tiling work shall be commenced only after the door and window frames are fixed and plastering of the walls/ ceiling is completed. Wall plastering shall not be carried out upto about 50mm above the level of proposed skirting/dado.

The base concrete shall be finished to a reasonably plane surface about 40 to 45mm below the level of finished floor. Before the tiling work is taken up, the base concrete or structural slab shall be cleaned of all loose materials, mortar droppings, dirt, laitance etc. using steel wire brush and well wetted without allowing any water pools on the surface.

A layer of 25mm average thickness of cement mortar consisting of one part of cement to 6 parts of sand shall be provided as bedding for the tiles over the base concrete. The thickness of bedding mortar shall not be less than 10mm at any place. The quantity of water to be added for the mortar shall be just adequate to obtain the workability for laying. Sand for the mortar shall conform to IS:2116 and shall have minimum fineness modulus of 1.5. The surface shall be left rough to provide a good bond for the tiles. The bedding shall be allowed to harden for a day before laying of the tilesNeat cement slurry using 4.4 kg of cement per sq.m of floor area shall be spread over the hardened mortar bedding over such an area at a time as would accommodate about 20 tiles. Tiles shall be fixed in this slurry one after the other, each tile being gently tapped with a wooden mallet till it is properly bedded and in level with the adjoining tiles. The joints shall be in straight lines and shall normally be 1.5mm wide. On completion of laying of the tiles in a room, all the joints shall be cleaned and washed fairly deep with a stiff broom/wire brush to a minimum depth of 5mm. The day after the tiles have been laid, the joints shall be filled with cement grout of the same shade as the colour of the matrix of the tile. For this purpose white cement or grey cement with or without pigments shall be used. The flooring should be kept moist and left undisturbed for 7 days for the bedding/joints to set properly. Heavy traffic shall not be allowed on the floor for atleast 14 days after fixing of the tiles.

About a week after laying the tiles, each and every tile shall be lightly tapped with a small wooden mallet to find out if it gives a hollow sound; if it does, such tiles along with any other cracked or broken tiles shall be removed and replaced with new tiles to proper line and level. The same procedure shall be followed again after grinding the tiles and all damaged tiles replaced, properly jointed and finished to match. For the purpose of ensuring that such replaced tiles match with those laid earlier, it is necessary that the Contractor shall procure sufficient quantity of extra tiles to meet this contingency.

Wherever a full tile cannot be provided, tiles shall be cut to size and fixed. Floor tiles adjoining the wall shall go about 10mm under the plaster, skirting or dado.

Tile skirting and dado work shall be executed only after laying tiles on the floor. For dado and skirting work, the vertical wall surface shall be thoroughly cleaned and wetted. Thereafter it shall be evenly and uniformly covered with 10mm thick backing of 1:4 cement sand mortar. For this work the tiles as obtained from the factory shall be of the size required and practically full polished. The back of each tile to be fixed shall be covered with a thin layer of neat cement paste and the tile shall then be gently tapped against the wall with a wooden mallet. Fixing shall be done from the bottom of the wall upwards. The joints shall be in straight lines and shall normally be 1.5mm wide. Any difference in the thickness of the tiles shall be evened out in the backing mortar or cement paste so that the tile faces are in conformity & truly plumb. Tiles for use at the corners shall be suitably cut with bevelled edges to obtain a neat and true joint. After the work has set, hand polishing with carborundum stones shall be done so that the surface matches with the floor finish. Contractor shall note that the unit rate quoted for skirting shall also include for any chipping of the brickwork required to be carried out for this item.

Wall plastering of the strip left out above the level of skirting/dado shall be taken up after the tiles are fixed. Chequered terrazzo tiles for flooring and for stair treads shall be delivered to site after the first machine grinding.

Machine grinding and polishing shall be commenced only after a lapse of 14 days of laying. The sequence and three numbers of machine grinding operations, usage of the type of carborundum stones, filling up of pin holes, watering etc. shall be carried out all as specified in IS:1443.

Tiles shall be laid to the levels specified. Where large areas are to be tiled the level of the central portion shall be kept 10mm higher than that at the walls to overcome optical illusion of a depression in the central portion. Localized deviation of ±3mm in any 3m length is acceptable in a nominally flat floor.

5A.8.15. In-Situ Terrazzo Work

5A.8.15.1 Materials

The requirements of marble aggregates for terrazzo topping shall be as per clause 8.14.1.

Cement shall first be mixed with the marble powder in dry state. The mix thus obtained shall be mixed with the aggregates in the specified proportions. Care shall be taken not to get the materials into a heap which results in the coarsest chips falling to the edges and cement working to the centre at the bottom. Materials shall be kept, as far as possible, in an even layer during mixing. After the materials have been thoroughly mixed in the dry state, water shall be added, just adequate to obtain plastic consistency for the desired workability for laying. The mix shall be used in the works within 30 minutes of the addition of water to the cement.

5A.8.15.2 Workmanship

The thickness, type, quality, size and colour of chips etc. for the in-situ terrazzo finish for flooring/dado/ skirting shall be as specified in the respective items of works. Laying and finishing of in-situ work shall conform to the requirements of workmanship stipulated in IS: 2114.

In-situ terrazzo finish shall be laid over hardened concrete base. The finish layer consists of an under layer and terrazzo topping. The underlayer shall be of cement concrete of mix 1:2:4 using 10mm down graded coarse aggregates. The combined thickness of under layer and topping shall not be less than 30 mm for flooring and 20mm for dado/skirting work.

The minimum thickness of topping shall be 6mm if chips used are between 1mm to 4mm, 9mm if chips are between 4mm to 7mm and 12mm if chips are between 7mm to 10mm. If chips larger than 10mm size are used, the minimum thickness shall be one and one third the maximum size of chips.

Both the underlayer and later the topping shall be divided into panels not exceeding 2 sq.m for laying so as to reduce the possibility of development of cracks. The longer dimension of any panel shall not exceed 2m. Dividing strips shall be used to separate the panels. When the dividing strips are not provided, the bays shall be laid alternately, allowing an interval of atleast 24 hours between laying adjacent bays.

Dividing strips shall be either of aluminium, brass or other material as indicated in the items of works. Aluminum strips should have a protective coating of bitumen. The thickness of the strips shall be not less than 1.5mm and width not less than 25mm for flooring work.

Concrete base shall be finished to a reasonably plane surface to a level below the finished floor elevation equal to the specified thickness of terrazzo finish. Before spreading the underlayer, the base concrete surface shall be cleaned of all loose materials, mortar droppings, dirt, laitance etc. and well wetted without allowing any water pools on the surface. Dividing strips or screed strips, if dividing strips are not provided shall be fixed on the base and levelled to the correct height to suit the thickness of the finish. Just before spreading the underlayer the surface shall be smeared with cement slurry at 2.75 Kg/sq.m. Over this slurry, the underlayer shall be spread and levelled with a screening board. The top surface shall be left rough to provide a good bond for the terrazzo topping.

Terrazzo topping shall be laid while the underlayer is still plastic and normally between 18 to 24 hours after the underlayer is laid. Cement slurry of the same colour as the topping shall be brushed on the surface immediately before laying is commenced. The terrazzo mix shall be laid to a uniform thickness and compacted thoroughly by tamping and with a minimum of troweling. Straight edge and steel floats shall be used to bring the surface true to the required level in such a manner that the maximum amount of marble chips come up and spread uniformly all over the surface.

The surface shall be left dry for air-curing for a period of 12 to 18 hours. Thereafter it shall be cured by allowing water to stand in pools for a period of not less than 4 days.

Machine grinding and polishing shall be commenced only after a lapse of 7 days from the time of completion of laying. The sequence and four numbers of machine grinding operations, usage of the type of carborundum stones, filling up of pinholes, wet curing, watering etc shall be carried out all as specified in IS: 2114.

5A.8.16. Shahabad / Tandur/ Kota Stone Slab/ Granite flooring work

5A.8.16.1 Materials

The slabs shall be of approved selected quality, hard, sound, dense and homogenous in texture, free from cracks, decay, weathering and flaws. The percentage of water absorption shall not exceed 5 percent as per test conducted in accordance with IS : 1124.

The slabs shall be hand or machine cut to the required thickness. Tolerance in thickness for dimensions of tile more than 100mm shall be ±5mm. This shall be ±2mm on dimensions less than 100mm.

Slabs shall be supplied to the specified size with machine cut edges or fine chisel dressed to the full depth. All angles and edges of the slabs shall be true and square, free from any chipping giving a plane surface. Slabs shall have the top surface machine polished (first grinding) before being brought to site. The slabs shall be washed clean before laying.

5A.8.16.2 Workmanship

The type, size, thickness and colour/shade etc. of the slabs for flooring/dado/skirting shall be as specified in the respective items of work.

Dado / skirting work shall be as per clause 5A.8.14.2. The thickness of the slabs for dado/skirting work shall not be more than 25mm. Slabs shall be so placed that the back surface is at a distance of 12mm. If necessary, slabs shall be held in position temporarily by suitable method. After checking for verticality, the gap shall be filled and packed with cement sand mortar of proportion 1:3. After the mortar has acquired sufficient strength, the temporary arrangement holding the slab shall be removed.

Grinding and polishing shall be as per clause 5A.8.14.2 except that first grinding with coarse grade carborundum shall not be done and cement slurry with or without pigment shall not be applied before polishing.

5A.8.17. Carborundum Tile Finish

5A.8.17.1 Materials

Carborundum tiles shall generally conform in all respects to the standards stipulated in IS:1237 for heavy duty tiles. Tiles shall be of the best quality manufactured adopting hydraulic pressure of not less than 14 N/mm^2.

The topping shall be uniform and of thickness not less than 6mm. The quantity of carborundum grit shall be not less than 1.35 kg/sq.m used with cement with or without pigment. The carborundum grit shall pass through 1.18mm mesh and shall be retained on 0.60 mm mesh.

The size, thickness, colour and plain or chequered etc of the tiles for flooring / skirting shall be as specified in the respective items of work.

5A.8.17.2 Workmanship

Requirements as detailed for terrazzo/cement tile finish under clause 5A.8.14.2 shall be applicable for carborundum tile flooring.

5A.8.18. Glazed Tile Finish

5A.8.18.1 Materials

Glazed earthenware tiles shall conform to the requirements of IS: 777. Tiles shall be of the best quality from an approved manufacturer. The tiles shall be flat, true to shape and free from flaws such as crazing, blisters, pinholes, specks or welts. Edges and underside of the tiles shall be free from glaze and shall have ribs or indentations for a better anchorage with the bedding mortar. Dimensional tolerances shall be as specified in IS: 777.

5A.8.18.2 Workmanship

The size, thickness, colour, with or without designs etc of the tiles for flooring/dado/skirting shall be as specified in the respective items of work.

The total thickness of glazed tile finish including the bedding mortar shall be 20 mm in flooring/dado/skirting. The minimum thickness of bedding mortar shall be 12mm for flooring and 10mm for dado/skirting work.

The bedding mortar shall consist of 1 part of cement to 3 parts of sand mixed with just sufficient water to obtain proper consistency for laying. Sand for the mortar shall conform to IS: 2116 and shall have minimum fineness modulus of 1.5.

Tiles shall be soaked in water for about 10 minutes just before laying. Where full size tiles cannot be fixed, tiles shall be cut to the required size using special cutting device and the edges rubbed smooth to ensure straight and true joints.

Colored tiles with or without designs shall be uniform and shall be preferably procured from the same batch of manufacture to avoid any differences in the shade.

Tiles for the flooring shall be laid over hardened concrete base. The surface of the concrete base shall be cleaned of all loose materials, mortar droppings etc well wetted without allowing any water pools on the surface. The bedding mortar shall then be laid evenly over the surface, tamped to the desired level and allowed to harden for a day. The top surface shall be left rough to provide a good bond for the tiles. For skirting and dado work, the backing mortar shall be roughened using a wire brush.

Neat cement slurry using 3.3 kg cement per sq.m of floor area shall be spread over the hardened mortar bed over such an area as would accommodate about 20 tiles. Tiles shall be fixed in this slurry one after the other, each tile being gently tapped with a wooden mallet till it is properly bedded and in level with the adjoining tiles. For skirting and dado work, the back of the tiles shall be smeared with cement slurry for setting on the backing mortar. Fixing of tiles shall be done from the bottom of the wall upwards. The joints shall be in perfect straight lines and as thin as possible but shall not be more than 1mm wide. The surface shall be checked frequently to ensure correct level/required slope. Floor tiles near the walls shall enter skirting/dado to a minimum depth of 10mm. Tiles shall not sound hollow when tapped.

All the joints shall be cleaned of grey cement with wire brush to a depth of atleast 3mm and all dust, loose mortar etc. shall be removed. White cement with or without pigment shall then be used for flush pointing the joints. Curing shall then be carried out for a minimum period of 7 days for the bedding and joints to set properly. The surface shall then be cleaned using a suitable detergent, fully washed and wiped dry.

Specials consisting of coves, internal and external angles, cornices, beads and their corner pieces shall be of thickness not less than the tiles with which they are used.

5A.8.19. In-Situ Cement Concrete Floor Topping

5A.8.19.1 Materials

The mix proportion for the in-situ concrete floor topping shall be 1:2.5:3.5 (one part cement: two and half parts sand: three and half parts coarse aggregates) by volume unless otherwise specified in the items of work.

The aggregates shall conform for the requirements of IS: 383.

Coarse aggregates shall have high hardness surface texture and shall consist of crushed rock of granite, basalt, trap or quartzite. The aggregate crushing valve shall not exceed 30 percent. The grading of the aggregates of size 12.5mm and below shall be as per IS: 2571.

Grading of the sand shall be within the limits indicated in IS: 2571.

5A.8.19.2 Workmanship

The thickness of the floor topping shall be as specified in the items of work. The minimum thickness of the floor topping shall be 25mm.

Preparation of base concrete/structural slab before laying the topping shall be as per clause 5A.8.13. The surface shall be rough to provide adequate bond for the topping.

Mixing of concrete shall be done thoroughly in a mechanical mixer unless hand mixing is specifically permitted by the Engineer. The concrete shall be as stiff as possible and the amount of water added shall be the minimum necessary to give just sufficient plasticity for laying and compacting. The mix shall be used in the work within 30 minutes of the addition of water for its preparation.

Floor finish shall be laid in suitable panels to reduce the risk of cracking. No dimension of a panel shall exceed 2 meters and the length of a panel shall not exceed one and a half times its breadth. Topping shall be laid in alternate panels, the intermediate panels being cast after a gap of atleast one day. Construction joints shall be plain vertical butt joints.

Screed strips shall be fixed dividing the area into suitable panels. Immediately before depositing the concrete topping, neat cement slurry at 2.75 kg/sq.m of area shall be thoroughly brushed into the prepared surface. Topping shall then be laid, very thoroughly tamped, struck off level and floated with wooden float. The surface shall then be tested with a straight edge and mason's spirit level to detect any inequalities and these shall be made good immediately.

Finishing of the surface by troweling shall be spread over a period of one to six hours depending upon the temperature and atmospheric conditions. The surface shall be trowelled 3 times at intervals so as to produce a smooth uniform and hard surface. Immediately after laying, the first trowelling just sufficient to give a level surface shall be carried out avoiding excessive trowelling at this stage. The surface shall be re- trowelled after sometime to close any pores and to scrap off excess water or laitance, which shall not be trowelled back into the topping. Final trowelling shall be done well before the concrete has become too hard but at a time when considerable pressure is required to make any impression on the surface. Sprinkling of dry cement or cement-sand mixture for absorbing moisture shall not be permitted.

Immediately after the surface is finished, it shall be protected suitably from rapid drying due to wind/ sunlight. After the surface has hardened sufficiently to prevent any damage to it, the topping shall be kept continuously moist for a minimum period of 10 days.

It is preferable to lay the topping on hardened base concrete, as against being laid monolithically with a lesser thickness, since proper levels and slopes with close surface tolerances is achievable in practice, owing to its greater thickness. Further, as this would be laid after all other building operations are over, there will be no risk of any damages or discoloration to the floor finish which are difficult to repair satisfactorily.

5A.8.20. In-Situ Granolithic Concrete Floor Topping

5A.8.20.1 Materials and Workmanship

The requirements of materials and workmanship shall be all as per clause 8.19 for in-situ cement concrete floor topping except that the mix proportion of the concrete shall be 1:1:2 (cement:sand:coarse aggregates) by volume.

The minimum thickness of granolithic floor topping on hardened concrete base shall be 40mm.

5A.8.21. Floor Hardener Topping

5A.8.21.1 Materials & Workmanship

Floor hardener topping shall be provided either as integrally finished over the structural slab/grade slab or laid monolithically with the concrete/granolithic floor finish on top of hardened concrete base.

Floor hardener of the metallic or non-metallic type suitable for the performance of normal / medium/ heavy duty function of the floor, the quantum of ingredients and the thickness of topping shall be as specified in the respective items of work.

For monolithic application with the floor finish/slab the thickness of the layer shall be 15mm. The topping shall be laid within 2 to 3 hours after concrete is laid when it is still plastic but stiffened enough for the workmen to tread over it by placing planks. The surface of the concrete layer shall be kept rough for providing adequate bond for the topping.   Laitance shall be removed before placing the topping. The topping shall be screened and thoroughly compacted to the finished level. Trowelling to a smooth finish shall be carried out as per clause 8.19.2. After the surface has hardened sufficiently, it shall be kept continuously moist for atleast 10 days.

The procedure for mixing the floor hardener topping shall be as per manufacturer's instructions.

Surface shall be prevented from any damages due to subsequent building operations by covering with 75 mm thick layer of sand.

5A.8.22. PVC Sheet/Tile Flooring

5A.8.22.1 Materials

PVC floor covering shall be of either unbacked homogeneous flexible type in the form of sheets/tiles conforming to IS: 3462 or homogeneous PVC asbestos tiles conforming to IS:3461.

The surface of the sheets/tiles shall be free from any physical defects such as pores, blisters, cracks etc. which affects the appearance and serviceability. Tiles/ sheets shall meet with the tolerance limits in dimensions specified in the IS. Contractor shall submit the test certificates, if so desired by the Engineer.

Each tile/sheet shall be legibly and indelibly marked with the name of the manufacturer or his trade mark, IS certificate mark, and batch number.

The adhesive to be used for laying the PVC flooring shall be rubber based and of the make as recommended and approved by the manufacturer of PVC sheets/tiles.

The type, size, colour, plain or mottled and the pattern shall be as specified in the respective items of work.

5A.8.22.2 Workmanship

PVC floor covering shall be provided over an underbed of cement concrete floor finish over the base concrete or structural slab. It is essential that the sub-floor and the underbed are perfectly dry before laying the PVC flooring. This shall be ensured by methods of testing as stipulated in Appendix-A of IS: 5318.

The surface of the underbed shall have trowelled finish without any irregularities which creates poor adhesion. Surface shall be free of oil or grease and thoroughly cleaned of all dust, dirt and wiped with a dry cloth.

PVC sheets/tiles shall be brought to the temperature of the area in which they are to be laid by stacking in a suitable manner within or near the laying area for a period of about 24 hours. Where air-conditioning is installed, the flooring shall not be laid on the underbed until the A/C units have been in operation for atleast 7 days. During this period, the temperature range shall be between 20deg.C and 30deg.C and this shall be maintained during the laying operations and also for 48 hours thereafter.

Layout of the PVC flooring shall be marked with guidelines on the underbed and PVC tiles/sheets shall be first laid for trial, without using the adhesive, according to the layout.

The adhesive shall be applied by using a notched trowel to the surface of the underbed and to the backside of PVC sheets/tiles. When the adhesive has set sufficiently for laying, it will be tacky to the touch, which generally takes about 30 minutes. The time period need be carefully monitored since a longer interval will affect the adhesive properties. Adhesive shall be uniformly spread over only as much surface area at one time which can be covered with PVC flooring within the stipulated time.

PVC sheet shall be carefully taken and placed in position from one end onwards slowly so that the air will be completely squeezed out between the sheet and the background surface and no air pockets are formed. It shall then be pressed with a suitable roller to develop proper contact. The next sheet shall be laid edge to edge with the sheet already laid, so that there is minimum gap between joints. The alignment shall be checked after each row of sheet is completed and trimmed if considered necessary.

Tiles shall be laid in the same manner as sheets and preferably, commencing from the centre of the area. Tiles should be lowered in position and pressed firmly on to the adhesive with minimum gap between the joints. Tiles shall not be slided on the surface. Tiles shall be rolled with a light wooden roller of about 5kg to ensure full contact with the underlay. Work should be constantly checked to ensure that all four edges of adjacent tiles meet accurately.

Any excess adhesive which may squeeze up between sheets/tiles shall be wiped off immediately with a wet cloth. Suitable solvents shall be used to remove hardened adhesive.

A minimum period of 24 hours shall be given after laying for the development of proper bond of the adhesive. When the flooring is thus completed, it shall be cleaned with a wet cloth soaked in warm soap solution.

Metallic edge strips shall be used to protect the edges of PVC sheets/tiles which are exposed as in doorways/ stair treads.

Hot sealing of joints between adjacent PVC sheet flooring to prevent creeping of water through the joints shall be carried out, using special equipment as per manufacturer's instructions.

5A.8.23. Acid Resisting Brick/Tiling Work

5A.8.23.1 Materials

The ceramic unglazed vitreous acid resisting tiles shall conform to the requirements of IS: 4457. Acid resistant bricks shall conform to the requirements of IS: 4860.

The finished tile/brick when fractured shall appear fine grained in texture, dense and homogeneous. Tile/brick shall be sound, true to shape, flat, free from flaws and any manufacturing defects affecting their utility. Tolerance in dimensions shall be within the limits specified in the respective IS.

The tiles/bricks shall be bedded and jointed using chemical resistant mortar of the resin type conforming to IS: 4832 (Part II). Method of usage shall generally be as per the requirements of IS: 4443.

5A.8.23.2 Workmanship

The size and thickness of tiles/size and class of bricks for use in the flooring/skirting/dado shall be as specified in the respective items of work.

The resin shall have viscosity for readily mixing with the filler by manual methods. The filler shall have graded particles which permit joint thickness of 1.5 mm.

The base concrete surface shall be free from dirt and thoroughly dried. The surface shall be applied with a coat of bitumen primer conforming to IS:3384. The primed surface shall then be applied with a uniform coat of bitumen conforming to IS:1580. Tiles or bricks shall be laid directly without the application of bitumen, if epoxy or polyester resin is used for the mortar.

Just adequate quantity of mortar which can be applied within the pot life as specified by the manufacturer shall be prepared at one time for bedding and jointing. Rigid PVC/Stainless steel/chromium plated tools shall be used for mixing and laying.

For laying the floor 6 to 8 mm thick mortar shall be spread on the back of the tile/brick. Two adjacent sides of the tile/brick shall be smeared with 4 to 6 mm thick mortar. Tile/brick shall be pressed into the bed and pushed against the floor and with the adjacent tile/ brick, until the joint in each case is 2 to 3 mm thick. Excess mortar shall then be trimmed off and allowed to harden fully. Similar procedure shall be adopted for the work on walls by pressing the tile/brick against the prepared wall surfaces and only one course shall be laid at a time until the initial setting period.

The mortar joints shall be cured for a minimum period of 72 hours with 20 to 25% hydrochloric acid or 30 to 40% sulphuric acid. After acid curing, the joints shall be washed with water and allowed to thoroughly dry. The joints shall then be filled with mortar to make them smooth and plane. Acid curing is not required to be carried out if epoxy or polyester resin is used for the mortar.

Resin mortars are normally self curing. The area tiled shall not be put to use before 48 hours in case epoxy, polyester and furane type of resin is used for the mortar. If phenolic or cashewnut shell liquid resin is used for the mortar, the area tiled shall not be put to use for 7 to 28 days respectively, without heat treatment. This period shall be 2 to 6 days respectively, if heat treatment is given with infrared lamp.

5A.8.24. Heavy Duty Abrasion Resistant Flooring

The type, quality, size, thickness, colour, etc., of the tile for flooring and skirting work shall be of the best quality approved by the Engineer. For this purpose, the Contractor shall provide the Engineer with necessary samples for this selection. Tiles shall be hardwearing, resistant to impact, resistant to abrasion, free from slipperiness and also resistant to attack by water, oils and greases.

5A.8.25. Epoxy Lining Work

5A.8.25.1 Materials

The epoxy resin and hardener formulation for laying of jointless lining work in floors and walls of concrete tanks/trenches etc shall be as per the requirements of IS: 9197.

The epoxy composition shall have the chemical resistance to withstand the following conditions of exposure:

a) Hydrochloric acid upto 30% concentration

b) Sodium hydroxide upto 50% concentration

c) Liquid temperature upto 60deg.C

d) Ultraviolet radiation

e) Alternate wetting and drying

Sand shall conform to grading zone III or IV of IS: 383.

The hardener shall be of the liquid type such as Aliphatic Amine or an Aliphatic/Aromatic Amine Adduct for the epoxy resin. The hardener shall react with epoxy resin at normal ambient temperature.

Contractor shall furnish test certificates for satisfying the requirements of the epoxy formulation if so directed by the Engineer.

5A.8.25.2 Workmanship

The minimum thickness of epoxy lining shall be 4 mm. It is essential that the concrete elements are adequately designed to ensure that water is excluded to permeate to the surface, over which the epoxy lining is proposed.

The epoxy lining shall be of the trowel type to facilitate execution of the required thickness for satisfactory performance.

The concrete surfaces over which epoxy lining is to be provided shall be thoroughly cleaned of oil or grease by suitable solvents, wire brushed to remove any dirt/dust and laitance. The surfaces shall then be washed with dilute hydrochloric acid and rinsed thoroughly with plenty of water or dilute ammonia solution. The surfaces shall then be allowed to dry. It is essential to ensure that the surfaces are perfectly dry before the commencement of epoxy application.

Just adequate quantity of epoxy resin which can be applied within the pot life as specified by the manufacturer shall be prepared at one time for laying and jointing.

Rigid PVC/stainless steel/chromium plated tools shall be used for laying. Trowelling shall be carried out to obtain uniformly the specified thickness of lining.

Lining shall be allowed to set without disturbance for a minimum period of 24 hours. The facility shall be put to use only after a minimum period of 7 days of laying of the lining.

5A.8.26. Polyurethane Coating

5A.8.26.1 Material

100% solids polyurethane coatings usually consist of two components: one isocyanate-rich solution and one polyol-rich solution. This has been defined in ASTM D16 Type V. Such a polyurethane coating film is formed when the above mentioned components are combined; a rapid and exothermic chemical polymerization reaction takes place. These two components are mixed in 1:1 solution.

By definition, the term "100% solids" means the coating system does not use any solvent to dissolve, carry or reduce any of the coating resins. Further, the resins normally still in a liquid state, will convert, 100%, to a solid film after application. The viscosity of the coating system is determined by the selection and design of the resin components. It is not determined by the addition of a solvent.

The properties of 100% solids polyurethanes vary from very soft, rubbery elastomers (like running shoe soles) to hard, ceramic like systems. The elastomers have a more linear structure with much less cross linking that allows them to be very stretchy and elastic. These systems normally have great impact strength and flexibility.

5A.8.26.2 Workmanship

The minimum thickness of polymer coating shall be 500 micron. It is essential that the concrete elements are adequately designed to ensure that water is excluded to permeate to the surface, over which the polymer coating is proposed.

This polyurethane coating is applied with a two component plural gun air less spray equipment. For RCC wall, one coat of moisture cured polyurethane primer is applied over the concrete surface. Over this primer, required coats of 100% Solid Elastomeric Polyurethane are applied. If the substrate is exposed to sun, one coat of Polyurethane aliphatic finish coat is applied.

For Elastomeric Polyurethane coat, it is required to use a two component airless spray gun equipment. The spray pumps are operated on hydraulic pressure.

For other coats of Moisture Cured Polyurethane, any standard spray equipment or brush application is OK.

5A.8.27. Water-Proofing

Machine made flat Yelahanka tiles shall be of the size and thickness as specified in the item of work. Tiles shall be soaked in water for atleast one hour before laying. The tiles shall be laid on a mortar bed of cement mortar 1:3 with an average thickness of 25mm. Tiles shall be laid, open jointed with 4 to 6 mm wide joints, flat on the mortar and lightly pressed and to set to plane surface true to slope, using trowel and wooden straight edge. They shall be laid with their longitudinal lines of joints truly parallel and generally at right angles to the direction on run-off gradient. Transverse joints in alternate rows shall come directly in line with each other. Transverse joints in adjacent courses shall break joints by atleast 50 mm. The joints shall be completely filled and flush pointed with cement mortar 1:3 mixed with red-oxide. Curing shall be carried out for a minimum period of seven days.

5A.8.27.1 General

The work shall include waterproofing for the building roofs, terraces, toilets, floor slabs, walls, planters, chajjas, sills and any other areas and at any other locations and situations as directed by the Engineer.

The waterproofing treatment shall be carried out on top of lime concrete (brick bat coba) laid to slope on roof surfaces. The brick bat coba shall be covered as specified below.

The work shall be carried out by an experienced specialist Sub-Contractor who shall be appointed only after prior approval of the Engineer.

5A.8.27.2 Modified Bituminous Membrane

Modified Bituminous Membrane shall be “SUPER THERMOLAY” 4 mm thick weighing 4 Kg/sqm, manufactured using APP Polymer modified bitumen with a central core of non-woven polyester reinforcement (200 gms/sqm) and with top and bottom layers of thermofusible film (top layer could also be sand finished) made by STP Limited in collaboration with Bitumat Company Limited. “PLYFLEX” of Bitumat Company Limited, Saudi Arabia supplied by STP Limited shall also be acceptable or other equivalent specification.

5A.8.27.3 Waterproofing of Roofs with Lime Concrete

Materials

Broken brick coarse aggregates prepared from well/over burnt bricks shall be well graded having a maximum size of 25mm and shall generally conform to IS:3068.

Lime shall be class C lime (fat lime) or factory made hydrated lime conforming to IS:712.

Workmanship

Lime concrete shall be prepared by thoroughly mixing the brick aggregates inclusive of brick dust obtained during breaking with the slaked lime in the proportions of 2 1/2 (two and a half) parts of brick aggregates to 1 part of slaked lime by volume. Water shall be added just adequate to obtain the desired workability for laying. Washing soap and alum shall be dissolved in the water to be used. The quantity of these materials required per cum of lime concrete shall be 12kg of washing soap and 4kg of alum. Brick aggregates shall be soaked thoroughly in water for a period of not less than six hours before use in the concrete mix. Lime concrete shall be used in the works within 24 hours after mixing.

The roof surface over which the water-proof treatment is to be carried out shall be cleaned of all foreign matter by wire brushing, dusting and made thoroughly dry. Preparation of surfaces shall be as stipulated in IS: 3067.

The slope of the finished waterproofing treatment shall be not less than 1 in 60 for efficient drainage. This shall be achieved either wholly in the lime concrete layer or otherwise as indicated in the drawings.

The average thickness of lime concrete, slope and the finish on top of machine made burnt clay flat terracing tiles conforming to IS:2690 (part I) shall be as specified in the items of work. The minimum compacted thickness of lime concrete layer shall be 75mm and average thickness shall not be less than 100mm. In case, the thickness is more than 100mm, it shall be laid in layers not exceeding 100mm to 125mm.

Laying of lime concrete shall be commenced from a corner of the roof and proceeded diagonally towards centre and other sides duly considering the slopes specified for effectively draining the rain-water towards the downtake points.

Lime concrete fillet for a minimum height of 150mm shall be provided all along the junction of the roof surface with the brick masonry wall/parapet/column projections. These shall then be finished on top with provision of clay terracing tiles/cement concrete tiles.

After the lime concrete is laid it shall be initially rammed with a rammer weighing not more than 2 Kg and the finish brought to the required evenness and slope. Alternatively, bamboo strips may be used for the initial ramming. Further consolidation shall be done using wooden THAPIES with rounded edges. The beating will normally have to be carried on for at least seven days until the THAPI makes no impression on the surface and rebounds readily from it when struck. Special care shall be taken to properly compact the lime concrete at its junction with parapet walls or column projections.

During compaction by hand-beating, the surface shall be sprinkled liberally with lime water (1 part of lime putty and 3 to 4 parts of water) and a small proportion of sugar solution for obtaining improved water-proofing quality of the lime concrete. On completion of beating, the mortar that comes on the top shall be smoothened with a trowel or float, if necessary, with the addition of sugar solution and lime putty. The sugar solution may be prepared in any one of the following ways as directed by the Engineer.

a) By mixing about 3 Kg of Jaggery and 1.5 Kg of BAEL fruit to 100 litres of water.

b) By mixing about 600 gm of KADUKAI (the dry nuts shall be broken to small pieces and allowed to soak in water), 200 gm of jaggery and 40 litres of water for 10 sq.m of work. This solution shall be brewed for about 12 to 24 hours and the resulting liquor decanted and used for the work.

The lime concrete after compaction shall be cured for a minimum period of seven days or until it hardens by covering with a thin layer of straw or hessian which shall be kept wet continuously.

Machine made flat terracing tiles shall be of the size and thickness as specified. Tiles shall be soaked in water for at least one hour before laying. Bedding for the tiles shall be 12mm thick in cement mortar 1:3. Tiles shall be laid, open jointed with 4 to 6 mm wide joints, flat on the mortar and lightly pressed and set to plane surface true to slope, using a trowel and wooden straight edge. They shall be laid with their longitudinal lines of joints truly parallel and generally at right angles to the direction of run-off gradient. Transverse joints in alternate rows shall come directly in line with each other. Transverse joints in adjacent courses shall break joints by atleast 50 mm. The joints shall be completely filled and flush pointed with cement mortar 1:2 mixed with water proofing compound as per manufacturer's instructions. Curing shall be carried out for a minimum period of seven days.

Finishing on top with cement concrete tiles or in-situ cement concrete floor topping shall be carried out in similar fashion as described for clay tiles in above the paragraph. Tiles to be used shall be supplied after the first machine grinding of the surface.

5A.8.27.5 Waterproofing of Roofs/Terraces etc.

Water proofing of Horizontal Surfaces

The waterproofing shall be applied as follows:

A coat of Blown Bitumen 85/25 shall be applied at the rate of 1.45 kg/sq.km

A roll of Modified Bituminous Membrane shall be unrolled over the primed surface and completely bonded to the substrate by pressing down evenly for the full width of the roll using a wooden roller. Torching shall be done, where recommended by the manufacturer and where directed by the Engineer-in-Charge, as the unrolling progresses.

The side overlaps shall be minimum 100 mm whereas the end overlaps shall be minimum 150 mm; both shall be bonded and sealed by flame torching.

Care shall be taken that the membrane is lapped with the treatment along the vertical surface and roof gutter treatment for at least 500 mm.

The membrane shall be properly overlapped/terminated at all openings, rainwater downtakes etc. to ensure that such junctions do not become sources of leakage.

Top of membrane finally shall be painted with antiglouse reflective paint.

Waterproofing of Vertical Surfaces at Roof Level and Gutters

The Water proofing shall be applied as described in (a) above.

Modified Bituminous membrane shall be unrolled and bonded to the substrate after applying a coat of bitumen and by pressing down evenly for the full width of the roll. Light torching shall be done to ensure complete bonding.

The membrane shall be overlapped with treatment for the horizontal surface by at least 500 mm.

The membrane shall be taken upto a pre-cut chase anchored and sealed.

5A.8.27.6 Khurras and Rainwater Down Pipes

Down pipes shall be isolated from RCC work with 6 mm polyethylene foam fixed with adhesive (Araldite) and sealed with silicone sealant prior to laying membrane. A water proofing flashing composed of one layer of Hessian based self finished felt Type 3 Grade 1 and two layers of aluminium foil of 0.075 mm thickness shall be provided. This flashing shall be carried into the down take pipes for at least 150 mm and sealed with hot bitumen. The Contractor shall closely coordinate the work with the agency providing and fixing the rainwater down take pipes.

5A.8.27.7 Testing

The treated area (flat and horizontal only) shall be tested by allowed water to stand on the treated areas to a depth of 150 mm for a minimum period of 72 hours.

The treated area (flat and horizontal) shall have continuous slope towards the rainwater outlets and no water shall pond anywhere on the surface.

5A.8.28. Cement Plastering Work

5A.8.28.1 Materials

The proportions of the cement mortar for plastering shall be 1:4 (one part of cement to four parts of sand). Cement and sand shall be mixed thoroughly in dry condition and then just enough water added to obtain a workable consistency. The quality of water and cement shall be as per relevant IS standards. The quality and grading of sand for plastering shall conform to IS: 1542. The mixing shall be done thoroughly in a mechanical mixer unless hand mixing is specifically permitted by the Engineer. If so desired by the Engineer sand shall be screened and washed to meet the Specifications. The mortar thus mixed shall be used as soon as possible preferably within 30 minutes from the time water is added to cement. In case the mortar has stiffened due to evaporation of water this may be re-tempered by adding water as required to restore consistency but this will be permitted only upto 30 minutes from the time of initial mixing of water to cement. Any mortar which is partially set shall be rejected and removed forthwith from the site. Droppings of plaster shall not be re-used under any circumstances.

5A.8.28.2 Workmanship

Preparation of surfaces and application of plaster finishes shall generally conform to the requirements specified in IS: 1661 and IS: 2402.

Plastering operations shall not be commenced until installation of all fittings and fixtures such as door/window panels, pipes, conduits etc. are completed.

All joints in masonry shall be raked as the work proceeds to a depth of 10mm/20mm for brick/stone masonry respectively with a tool made for the purpose when the mortar is still green. The masonry surface to be rendered shall be washed with clean water to remove all dirt, loose materials, etc., Concrete surfaces to be rendered shall be roughened suitably by hacking or bush hammering for proper adhesion of plaster and the surface shall be evenly wetted to provide the correct suction. The masonry surfaces should not be too wet but only damp at the time of plastering. The dampness shall be uniform to get uniform bond between the plaster and the masonry surface.

Interior plain faced plaster - This plaster shall be laid in a single coat of 13mm thickness. The mortar shall be dashed against the prepared surface with a trowel. The dashing of the coat shall be done using a strong whipping motion at right angles to the face of the wall or it may be applied with a plaster machine. The coat shall be trowelled hard and tight forcing it to surface depressions to obtain a permanent bond and finished to smooth surface. Interior plaster shall be carried out on jambs, lintel and sill faces, etc. as shown in the drawing and as directed by the Engineer.

Plain Faced Ceiling plaster - This plaster shall be applied in a single coat of 6mm thickness. Application of mortar shall be as stipulated in above paragraph.

Exterior plain faced plaster - This plaster shall be applied in 2 coats. The first coat or the rendering coat shall be approximately 14mm thick. The rendering coat shall be applied as stipulated above except finishing it to a true and even surface and then lightly roughened by cross scratch lines to provide bond for the finishing coat. The rendering coat shall be cured for atleast two days and then allowed to dry. The second coat or finishing coat shall be 6 mm thick. Before application of the second coat, the rendering coat shall be evenly damped. The second coat shall be applied from top to bottom in one operation without joints and shall be finished leaving an even and uniform surface. The mortar proportions for the coats shall be as specified in the respective item of work. The finished plastering work shall be cured for atleast 7 days.

Interior plain faced plaster 20mm thick if specified for uneven faces of brick walls or for random/coursed rubble masonry walls shall be executed in 2 coats similar to the procedure stipulated in above paragraph.

Exterior Sand Faced Plaster- This plaster shall be applied in 2 coats. The first coat shall be approximately 14mm thick and the second coat shall be 6mm thick. These coats shall be applied as stipulated above. However, only approved quality white sand shall be used for the second coat and for the finishing work. Sand for the finishing work shall be coarse and of even size and shall be dashed against the surface and sponged. The mortar proportions for the first and second coats shall be as specified in the respective items of work.

Wherever more than 20mm thick plaster has been specified, which is intended for purposes of providing beading, bands, etc. this work shall be carried out in two or three coats as directed by the Engineer duly satisfying the requirements of curing each coat (rendering/floating) for a minimum period of 2 days and curing the finished work for atleast 7 days.

In the case of pebble faced finish plaster, pebbles of approved size and quality shall be dashed against the final coat while it is still green to obtain as far as possible a uniform pattern all as directed by the Engineer.

Where specified in the drawings, rectangular grooves of the dimensions indicated shall be provided in external plaster by means of timber battens when the plaster is still in green condition. Battens shall be carefully removed after the initial set of plaster and the broken edges and corners made good. All grooves shall be uniform in width and depth and shall be true to the lines and levels as per the drawings.

Curing of plaster shall be started as soon as the applied plaster has hardened sufficiently so as not to be damaged when watered. Curing shall be done by continuously applying water in a fine spray and shall be carried out for at least 7 days.

For waterproofing plaster, the Contractor shall provide the water-proofing admixture as specified in manufacturers instruction while preparing the cement mortar.

For external plaster, the plastering operations shall be commenced from the top floor and carried downwards. For internal plaster, the plastering operations for the walls shall commence at the top and carried downwards. Plastering shall be carried out to the full length of the wall or to natural breaking points like doors/windows etc. Ceiling plaster shall be completed first before commencing wall plastering.

Double scaffolding to be used shall be as specified in clause 5A.8.2.2.

The finished plaster surface shall not show any deviation more than 4mm when checked with a straight edge of 2m length placed against the surface.

To overcome the possibility of development of cracks in the plastering work following measures shall be adopted.

a) Plastering work shall be deferred as much as possible so that fairly complete drying shrinkage in concrete and masonry works takes place.

b) Steel wire fabric shall be provided at the junction of brick masonry and concrete to overcome reasonably the differential drying shrinkage/thermal movement.

Ceiling plaster shall be done, with a trowel cut at its junction with wall plaster. Similarly trowel cut shall be adopted between adjacent surfaces where discontinuity of the background exists.

5A.8.29. Cement Pointing

5A.8.29.1 Materials

The cement mortar for pointing shall be in the proportion of 1:3 (one part of cement to three parts of fine sand). Sand shall conform to IS: 1542 and shall be free from clay, shale, loam, alkali and organic matter and shall be of sound, hard, clean and durable particles. Sand shall be approved by Engineer and if so directed it shall be washed/screened to meet specification requirements.

5A.8.29.2 Workmanship

Where pointing of joints in masonry work is specified, the joints shall be raked at least 15mm/20mm deep in brick/stone masonry respectively as the work proceeds when the mortar is still green.

Any dust/dirt in the raked joints shall be brushed out clean and the joints shall be washed with water. The joints shall be damp at the time of pointing. Mortar shall be filled into joints and well pressed with special steel trowels. The joints shall not be disturbed after it has once begun to set. The joints of the pointed work shall be neat. The lines shall be regular and uniform in breadth and the joints shall be raised, flat, sunk or 'V' as may be specified in the respective items of work. No false joints shall be allowed.

The work shall be kept moist for atleast 7 days after the pointing is completed. Whenever coloured pointing has to be done, the colouring pigment of the colour required shall be added to cement in such proportions as recommended by the manufacturer and as approved by the Engineer.

5A.8.30. Metal Lath and Wire Fabric

5A.8.30.1 Materials

Welded steel wire fabric shall conform to IS: 4948.

Expanded metal shall conform to IS: 412.

Galvanised wire mesh shall be of approved quality.

5A.8.30.2 Workmanship

The type and details of the steel material to be used for metal lath plastering work and at the junctions of brick masonry/concrete before wall plastering shall be as specified in the respective items of work.

For metal lath plastering work, the weight of steel material shall be not less than 1.6 kg/sq.m.

Steel material for use at the junction of brick masonry/concrete shall have the mesh dimensions not greater than 50 mm.

Steel material shall be obtained in maximum lengths as manufactured to restrict joints to the minimum. Overlap at the joints shall be minimum 25 mm which shall be securely tied with wires of diameter not less than 1.25 mm at spacings not more than 100 mm for lath plastering work. Nailing to wall shall be at spacings not exceeding 200 mm. The material shall be straightened, cut and bent to shape if required for fixing as per the details indicated in the drawings.

5A.8.31. Water-Proofing Admixtures

Water-proofing admixture shall conform to the requirements of IS: 2645 and shall be of approved manufacture. The admixture shall not contain calcium chloride. The quantity of the admixture to be used for the works and method of mixing etc. shall be as per manufacturer's instructions and as directed by the Engineer.

5A.8.32. Painting of Concrete, Masonry & Plastered Surfaces

5A.8.32.1 Materials

Oil bound distemper shall conform to IS: 428. The primer shall be alkali resistant primer of the same manufacture as that of the distemper.

Cement paint shall conform to IS: 5410. The primer shall be a thinned coat of cement paint.

Lead free acid, alkali and chlorine resisting paint shall conform to IS: 9862.

White wash shall be made from good quality fat lime conforming to IS: 712. It shall be slaked at site and mixed with water in the proportion of 5 litres of water to 1 kg of unslaked lime stirred well to make a thin cream. This shall be allowed to stand for a minimum period of one day and strained through a clean coarse cloth. Four kg of gum dissolved in hot water shall be added to each cum of cream. 1.30 kg of sodium chloride dissolved in hot water shall then be added per 10 kg of lime used for the white wash to be ready for application.

Colour wash shall be made by addition of a suitable quantity of mineral pigment, not affected by lime, to the prepared white wash to obtain the shade/tint as approved by the Engineer.

All the materials shall be of the best quality from an approved manufacturer. Contractor shall obtain prior approval of the Engineer for the brand of manufacture and the colour/shade. All materials shall be brought to the site of works in sealed containers.

5A.8.32.2 Workmanship

Contractor shall obtain the approval of the Engineer regarding the readiness of the surfaces to receive the specified finish, before commencing the work on painting. Painting of new surfaces shall be deferred as much as possible to allow for thorough drying of the sub- strata. The surfaces to be treated shall be prepared by thoroughly brushing them free from dirt, mortar droppings and any loose foreign materials. Surfaces shall be free from oil, grease and efflorescence. Efflorescence shall be removed only by dry brushing of the growth. Cracks shall be filled with Gypsum. Workmanship of painting shall generally conform to IS: 2395. Surfaces of doors, windows etc. shall be protected suitably to prevent paint finishes from splashing on them.

5A.8.32.3 White Wash

The prepared surfaces shall be wetted and the finish applied by brushing. The operation for each coat shall consist of a stroke of the brush first given horizontally from the right and the other from the left and similarly, the subsequent stroke from bottom upwards and the other from top downwards, before the first coat dries. Each coat shall be allowed to dry before the next coat is applied. Minimum of 2 coats shall be applied unless otherwise specified. The dry surface shall present a uniform finish without any brush marks.

5A.8.32.4 Colour Wash

Colour wash shall be applied in the same way as for white wash. A minimum of 2 coats shall be applied unless otherwise specified. The surface shall present a smooth and uniform finish without any streaks. The finished dry surface shall not show any signs of peeling/powdery and come off readily on the hand when rubbed.

5A.8.32.5 Cement Paint

The prepared surfaces shall be wetted to control surface suction and to provide moisture to aid in proper curing of the paint. Cement paint shall be applied with a brush with stiff bristles. The primer coat shall be a thinned coat of cement paint. The quantity of thinner shall be as per manufacturer's instructions. The coats shall be vigorously scrubbed to work the paint into any voids for providing a continuous paint film free from pinholes for effective water proofing in addition to decoration. Cement paint shall be brushed in uniform thickness and the covering capacity for two coats on plastered surfaces shall be 3 to 4 kg/sq.m. A minimum of 2 coats of the same colour shall be applied. Atleast 24 hours shall be left after the first coat to become sufficiently hard before the second coat is applied. The painted surfaces shall be thoroughly cured by sprinkling with water using a fog spray at least 2 to 3 times a day. Curing shall commence after about 12 hours when the paint hardens. Curing shall be continued for atleast 2 days after the application of final coat. The operations for brushing each coat shall be as detailed above.

5A.8.32.6 Oil bound Distemper

The prepared surfaces shall be dry and provided with one coat of alkali resistant primer by brushing. The surface shall be finished uniformly without leaving any brush marks and allowed to dry for atleast 48 hours. A minimum of two coats of oil bound distemper shall be applied, unless otherwise specified. The first coat shall be of a lighter tint. Atleast 24 hours shall be left after the first coat to become completely dry before the application of the second coat. Broad, stiff, double bristled distemper brushes shall be used for the work. The operations for brushing each coat shall be as detailed above.

5A.8.32.7 Acid, Alkali Resisting Paint

A minimum of 2 coats of acid/alkali resisting paint shall be applied over the prepared dry surfaces by brushing. Primer coat shall be as per manufacturer's instructions.

5A.8.32.8 Plastic Emulsion Paint

The prepared surface shall be dry and provided with one coat of primer which shall be a thinned coat of emulsion paint. The quantity of thinner shall be as per manufacturer's instructions. The paint shall be laid on evenly and smoothly by means of crossing and laying off. The crossing and laying off consists of covering the area with paint, brushing the surface hard for the first time over and then brushing alternately in opposite directions two or three times and then finally brushing lightly in a direction at right angles. In this process, no brush marks shall be left after the laying off is finished. The full process of crossing and laying off constitutes one coat. The next coat shall be applied only after the first coat has dried and sufficiently become hard which normally takes about 2 to 3 hours. A minimum of 2 finishing coats of the same colour shall be applied unless otherwise specified. Paint may also be applied using rollers. The surface on finishing shall present a flat velvety smooth finish and uniform in shade without any patches.

5A.8.32.9 Acrylic Emulsion Paint

Acrylic emulsion paint shall be applied in the same way as for plastic emulsion paint. A minimum of 2 finishing coats over one coat of primer shall be provided unless otherwise specified.

5A.8.33. Painting & Polishing of Wood Work

5A.8.33.1 Materials

Wood primer shall conform to IS: 3536.

Filler shall conform to IS: 110.

Varnish shall conform to IS: 337.

French polish shall conform to IS: 348.

Synthetic enamel paint shall conform to IS: 2932.

All the materials shall be of the best quality from an approved manufacturer. Contractor shall obtain prior approval of the Employer’s Representative for the brand of manufacture and the colour/shade. All materials shall be brought to the site of works in sealed containers.

5A.8.33.2 Workmanship

The type of finish to be provided for woodwork of painting or polishing, the number of coats, etc. shall be as specified in the respective items of work to be prepared by the Contractor.

Primer and finish paint shall be compatible with each other to avoid cracking and wrinkling. Primer and finish paint shall be from the same manufacturer.

Painting shall be either by brushing or spraying. Contractor shall procure the appropriate quality of paint for this purpose as recommended by the manufacturer. The workmanship shall generally conform to the requirements of IS: 2338 (Part I).

All the wood surfaces to be painted shall be thoroughly dry and free from any foreign matter. Surfaces shall be smoothened with abrasive paper using it across the grains and dusted off. Wood primer coat shall then be applied uniformly by brushing. The number of primer coats shall be as specified in the item of work to be prepared by the Contractor. Any slight irregularities of the surface shall then be made- up by applying an optimum coat of filler conforming to IS: 110 and rubbed down with an abrasive paper for obtaining a smooth surface for the undercoat of synthetic enamel paint conforming to IS:2932. Paint shall be applied by brushing evenly and smoothly by means of crossing and laying off in the direction of the grain of wood. After drying, the coat shall be carefully rubbed down using very fine grade of sand paper and wiped clean before the next coat is applied. Atleast 24 hours shall elapse between the application of successive coats. Each coat shall vary slightly in shade and this shall be got approved by the Employer's Representative. The number of coats of paint to be applied shall be as specified in the item of work to be prepared by the Contractor.

All the wood surfaces to be provided with clear finishes shall be thoroughly dry and free from any foreign matter. Surfaces shall be smoothened with abrasive paper using it in the direction of the grains and dusted off. Any slight irregularities of the surface shall be made up by applying an optimum coat of transparent liquid filler and rubbed down with an abrasive paper for obtaining a smooth surface. All dust and dirt shall be thoroughly removed. Over this prepared surface, varnish conforming to IS:337 shall be applied by brushing. Varnish should not be retouched once it has begun to set. Staining if required shall be provided as directed by the Employer's Representative. When two coats of varnish is specified, the first coat should be a hard-drying undercoat or flatting varnish which shall be allowed to dry hard before applying the finishing coat. The number of coats to be applied shall be as specified. For works where clear finish of French polish is specified the prepared surfaces of wood shall be applied with the polish using a pad of woolen cloth covered by a fine cloth. The pad shall be moistened with polish and rubbed hard on the surface in a series of overlapping circles to give an even finish over the entire area. The surface shall be allowed to dry before applying the next coat. Finishing shall be carried out using a fresh clean cloth over the pad, slight dampening with methylated spirit and rubbing lightly and quickly in circular motions. The finished surface shall have a uniform texture and high gloss. The number of coats to be applied shall be as specified.

5A.8.34. Painting of Steel Work

5A.8.34.1 Materials

Red-oxide – zinc chrome primer shall conform to IS: 2074.

Synthetic enamel paint shall conform to IS: 2932.

Aluminium paint shall conform to IS: 2339.

All the materials shall be of the best quality from an approved manufacturer. Contractor shall obtain prior approval of the Employer's Representative for the brand of manufacture and the colour/shade. All the materials shall be brought to the site in sealed containers.

5A.8.34.2 Workmanship

Painting work shall be carried out only on thoroughly dry surfaces. Painting shall be applied either by brushing or by spraying. Contractor shall procure the appropriate quality of paint for this purpose as recommended by the manufacturer. The workmanship shall generally conform to the requirement of IS: 1477 (Part 2).

The type of paint, number of coats etc. shall be as specified in the respective items of work.

Primer and finish paint shall be compatible with each other to avoid cracking and wrinkling. Primer and finish paint shall be from the same manufacturer.

All the surfaces shall be thoroughly cleaned of oil, grease, dirt, rust and scale. The methods to be adopted using solvents, wire brushing, power tool cleaning etc., shall be as per IS: 1477 (Part – I) and as indicated in the item of work.

It is essential to ensure that immediately after preparation of the surfaces, the first coat of red oxide-zinc chrome primer shall be applied by brushing and working it well to ensure a continuous film without holidays. After the first coat becomes hard dry, a second coat of primer shall be applied by brushing to obtain a film free from `holidays'.

After the second coat of primer is hard dry, the entire surface shall be wet rubbed cutting down to a smooth uniform surface. When the surface becomes dry, the undercoat of synthetic enamel paint of optimum thickness shall be applied by brushing with minimum of brush marks. The coat shall be allowed to hard-dry. The under coat shall then be wet rubbed cutting down to a smooth finish, taking adequate care to ensure that at no place the undercoat is completely removed. The surface shall then be allowed to dry.

The first finishing coat of paint shall be applied by brushing and allowed to hard-dry. The gloss from the entire surface shall then be gently removed and the surface dusted off. The second finishing coat shall then be applied by brushing.

Atleast 24 hours shall elapse between the application of successive coats. Each coat shall vary slightly in shade and this shall be got approved by the Employer's Representative.

5A.8.35. Flashing

5A.8.35.1 Materials

Anodised Aluminium sheets shall be 1.00mm thick with anodic film thickness of 0.025 mm.

Galvanised mild steel sheets shall be 1.00mm thick with zinc coating of 800 gms/sq.m.

Bitumen felt shall be either Hessian base self finished bitumen felt Type-3 Grade I conforming to IS:1322 or glass fibre base self finished felt Type-2 Grade 1 conforming to IS:7193.

5A.8.35.2 Workmanship

The type of the flashing and method of fixing shall be as specified.

Flashing shall be of the correct shape and size as indicated in the construction drawings and they shall be properly fixed to ensure their effectiveness.

Flashing shall be of long lengths so as to provide minimum number of joints. The minimum overlap at joints shall be 100mm.

Fixing of the flashing shall be either by bolting with bitumen washers or by tucking into the groove 75 mm wide x 65 mm deep in masonry/concrete along with cement mortar 1:4 filletting as indicated in the Drawings. Curing of the mortar shall be carried out for a minimum period of 4 days.

Bitumen felt flashing of the type as specified shall be provided with 2 coats of bituminous paint at the rate of 0.10 litre/sq.m after the installation.

5A.8.36. Thermal Insulation For Ceiling

Thermal insulation shall be “Thermocole” TF type or similar approved or Resin bonded fibre glass boards.

5A.8.36.1 “Thermocole” Boards

Soffit of R.C. slab shall be thoroughly cleaned with wire brush and 85/25 industrial grade hot bitumen conforming to IS: 702 shall be applied uniformly over the surface at the rate of 1.5 Kg/m^2.

Thermocole boards (T.F. variety) of 50mm thickness shall be stuck by means of the same grade of hot bitumen.

The boards shall be further secured with screws, washers and plugs.

The joints of the boards shall be sealed with bitumen.

5A.8.36.2 Fibre Glass Boards

Timber pegs 50mm x 50mm x 50mm shall be fixed to the slab at 600mm centres with 6mm x 65mm long wood screws. 20 gauge G.I. lacing wire shall be tied to the pegs.

`Crown’ 200 fibreglass boards 50mm thick shall be stuck to the pegs with CPRX compound or any other suitable adhesive and be held in position by the 20 gauge G.I. lacing wires.

The insulation boards shall be covered with 20mm – 24 gauge hexagonal G.I. chicken wire mesh, nailed to the timber pegs and 30 gauge aluminium sheets shall be fixed over the chicken wire mesh with 50mm overlap and secured to the timer pegs by screws.

If the insulation is specified to rest on top of the false ceiling, it shall be properly installed and anchored to the framework. In case additional battens are required for proper installation, Contractor shall include its cost in the rate for insulation.

5A.8.37. Plaster of Paris Board False Ceiling

5A.8.37.1 Plaster of Paris Boards

The plaster of paris boards to be used in the false ceiling shall be of an approved manufacture or manufactured at site by methods and materials approved by Engineer.

The plaster of paris shall be of the calcium-sulphate hemi-hydrate variety and shall contain not less than 35 percent sulphur trioxide and other requirements as per IS:2547 (Part I) However, its fineness shall be such that the residue, after drying, and sieving on I.S. sieve designation 3.35mm for 5 minutes shall not be more than 1 percent by weight. Initial setting time shall not be less than 13 minutes. The average compressive strength of plaster determined by testing 5 cm cubes 24 hours after removal from moulds and drying in an oven at 40 Deg. C till the weight of the cubes is constant, shall not be less than 84 kg per sq.cm.

The plaster of paris boards reinforced with hessian cloth or coir shall be prepared in suitable sizes as shown on the drawings or as directed by the Engineer. Wooden forms of height equal to the thickness of boards shall be placed on truly level and smooth surface such as a glass sheet. The edges of the boards shall be truly square. The glass sheet or surface on which form is kept and the form sides shall be given a thin coat of non-staining oil to facilitate the easy removal of the board. Plaster of paris shall be evenly spread into the form upto about half the depth and hessian cloth or coir shall be pressed over the plaster of paris layer. The weight of hessian cloth or coir in the board shall be 250 gm per sq.m. The ends of the hessian/coir reinforcement shall be turned over at all edges to form a double layer for a width of 50mm. The hessian cloth shall be of an open web texture so as to allow the plaster below and above to intermix with each other and form an integral board. The form shall then be filled with plaster of paris which shall be uniform pressed and then wire cut to an even and smooth surface. The board shall then be allowed to set initially for an hour or so and then removed from the form and allowed to dry and harden for about a week. The board after drying and hardening shall give a ringing sound when struck. The boards shall be true and exact to shape and size and the exposed face shall be truly plane and smooth.

The size of boards shall generally be 600mm x 600 mm x 12 mm thick. Boards shall be kept dry in transit and stored flat in a clean dry place and shall not be exposed to moisture. The boards shall always be carried on edges.

5A.8.37.2 Metal Framework

The metal frame work may be made of sections of light metal, such as anodised aluminium, mild steel or as shown on the drawings. The shape of cross-section shall be such as to facilitate proper suspension and proper fixing of the ceiling boards covering them and shall be structurally sound and rigid.

5A.8.38. Construction

Contractor shall ensure that the frame to support the ceiling is designed for structural strength and the sizes, weight and strength of ceiling boards to be fixed and other loads due to live load, air-conditioning ducts, grills, electrical wiring and lighting fixtures, thermal insulation, etc. as shown on the drawings. Contractor shall also submit a detailed drawing to show the grid work, sizes of grid members, method of suspension, position of openings for air-conditioning and lighting, access doors, etc.

The false ceiling grid work shall be carried out as per the approved drawings or as directed by Engineer. In case of timber grid work, the grid work shall consist of teak wood runners of minimum size 60mm deep x 40mm wide along one direction at 1.2m centre to centre and secondary runners of size 50mm deep x 40 mm wide at 60mm centre to centre perpendicular to the main runners.

The metal frame work when it is anodised aluminium false ceiling grid system shall consist of aluminium main member of special T-Profile of 38mm x 38mm x 1.5mm thick, interlocking with each other to form frames of various sizes, 600mm x 600 mm or as shown on the drawing. The main members shall be suspended from the roof structures by means of steel hangers as described for timber frame work and supported at the walls by means of anodised aluminium wall angles.

In the case of timber frame work, all the edges of the plaster of paris board shall be fixed to frame members by means of counter sunk and rustless screws of 2.74 mm size, 40mm long at a spacing of 100mm to 150 mm c/c and 12mm from the edge of the board. Holes for screws shall be drilled and screws slightly countersunk into the boards. The boards shall be fixed to wooden framework with a joint clearance of about 3mm. The joints shall always be in perfect line and plane.

In case of aluminium grid system, boards shall be just placed into the frames formed by the main `T' members and the cross members fitted with the clips for locking boards. Contractor shall take utmost care so as not to force the boards in position and a slight gap shall be provided so as not to make a tight joint. The boards shall be cut with a saw, if required, to any shape and size.

As the work of false ceiling may be inter-connected with the work of air-conditioning ducts and lighting, Contractor shall fully co-operate with the other agencies entrusted with the above work, who may be working simultaneously.Contractor shall provide necessary openings in the false ceiling work for air-conditioning, lighting and other fixtures. Additional framing, if required, for the above opening shall also be provided at no extra cost to the Employer. Removable or hinged type inspection or access trap doors shall be provided at locations specified by the Engineer.

5A.8.38.1 Finishing

It is essential that false ceiling work should be firm and in perfect line and level and all boards free from distortion, bulge, and other defects. All defective boards and other material shall be removed from site immediately and replaced, and ceiling restored to original finish to the satisfaction of Engineer.

The workmanship shall be of highest order and all joinery work for timber work shall be in the best workmanship manner. The joints for aluminium frame work shall be of inter-locking type so that when the cross member is in place, it cannot be lifted out.

The countersunk heads of screws and all joints shall be filled with plaster of paris and finished smooth. After filling the joints, a thick skin of the finishing material shall be spread about 50mm wide on either side of the joint and on to it shall be trowelled dry a reinforcing scrim cloth about 10mm wide. If metal scrim is used, a stiffer plaster will be necessary to enable the trowelling of the scrim down to the board.

5A.8.38.2 Fire Stopping

In case of fire protective ceilings, fire resisting barriers at suitable intervals shall be provided . These shall completely close the gap between the false ceiling and soffit of the structural slab. The material of the barrier shall be as indicated by Engineer (Reference may be made to the British Standards Institutions CP 290: Code of Practice for suspended ceiling and lining of dry construction using metal fixing system, `for guidance).

5A.8.39. False or Cavity Floor

5A.8.39.1 Frame Work

The false floor shall consist of a framework of suitable structural member designed to carry the loads specified. This frame work shall be supported on suitably designed stools placed at 600mm centre to centre in both directions. The stools shall consist of a mild steel base plate with a mild steel stud having adjustable lock nut and coupling at the centre and another mild steel plate at top serving as a prophead. The above framework shall be suitably designed to accommodate 35mm thick, 600mm square panels. The base plate shall be fixed to the reinforced concrete floor with an approved adhesive compound or with 4 Nos. 6mm dia. anchor fasteners. Bedding of 1:2 or richer cement sand mortar shall be provided locally under the base plates of stools to provide a level surface.

The prophead shall be provided with mild steel lugs welded on top and each placed perpendicular to the other for proper positioning and supporting the main and cross members. The stools shall be capable of adjustment to accommodate concrete floor level irregularities upto plus or minus 15mm. The framing members shall be completely removable and shall remain in position without screwing or bolting to the propheads. All steel framework including steel stools shall be given a coat of zinc chromate primer and two coats of enamel paint of approved colour and shade.

5A.8.39.2 Floor Panels

The floor panels shall be made of 600mm x 600mm x 35 mm thick medium density unveneered/ non-prelaminated teak wood particle boards having a density of not more than 800 kg/cum bonded with boiling water proof phenol formaldehyde synthetic resin and shall be of fire resistant, termite resistant and moisture proof quality, generally conforming to IS: 3087-specification for wood particle boards (Medium Density) for general purposes.

The thermal conductivity of the boards shall not exceed 0.12 k Cal/hr/sq.m/deg./C/m.

The panel size given above may be suitably modified near electrical panel/equipment and also to suit room dimensions with panel size not more than 600mm under any circumstances. Exposed 2mm thick vinyl edging shall be provided on all edges of individual panels. Each panel shall be given a coat or primer and two coats of approved fire resistant paint from underside.

The particle boards shall be faced with 600mm x 600 mm x 2mm thick approved make flooring tiles conforming to IS:3462 and of approved colour and shade. The completed panel shall be completely removable and shall remain in position without screwing or bolting to the supporting framework. Each floor panel shall be marked on the inner side with stickers for easy identification and reassembly whenever required.

Suitable backing material shall be provided on the underside of the particle board to prevent warping and / or to cater to specified loading.

Suitable removable covers shall be provided to serve as outlets for the cables.

5A.8.39.3 Finished Height of False Flooring

The finished height from top of reinforced concrete floor to the finished floor surface of false/cavity floor shall be as specified or as shown on drawings.

5A.8.39.4 Ramps and Steps

Ramps and steps shall be provided as shown on the Engineer's drawing and as directed by the Engineer without any extra cost to the Employer.

5A.8.39.5 Imposed Loading

The finished floor shall be capable of supporting a uniformly distributed loads of 500 to 1000 Kg. per sq. metre of floor area as specified in data sheet. A point load of 450 Kg on 600 sq.mm on any part of the panel or a line load of 725 Kg on 100mm strip across the panel length shall not result in a deflection greater than 2.5mm.

5A.8.39.6 Finish

The finished floor shall be true to lines and levels and present a neat flush surface.

5A.8.39.7 General

Supply shall be made by a specialist supplier who is to be approved by Engineer. Supplier shall prepare and submit a layout drawing for false floor giving all details including supporting system for approval. If so called for, supplier shall also submit his calculations for the supporting system with all relevant data assumed, to the Engineer for his approval. Work shall be carried out on approved drawings only.

5A.8.39.9 Vendor Drawing

Vendor shall prepare and submit a layout drawing for false floor giving all details including supporting system for approval. If so called for, vendor shall also submit his calculations for the supporting system with all relevant data assumed, to the Employer's Representative for his approval. Work shall be carried out on approved drawings only.

5A.8.40. Fire Proof Doors

5A.8.40.1 Material and Workmanship

The design of fire proof doors and the materials to be used in their fabrication have to be such that they shall be capable of providing the effective barrier to the spread of fire. The materials, fabrication and erection of fire proof doors shall confirm to IS: 3614 (Part – I). The fire proof doors shall be obtained from an approved manufacturer. Specific approval for such purchase shall be obtained before hand.

Sample approval shall also be obtained from testing authority as per the standard IS: 3614 (Part – 2) for the specified degree of fire rating in hours. All fire proof doors shall have specified sizes and confirm to the description in the respective items of work.

Fire proof door shutters shall be of zinc coated weldable steel (confirming to BS: 6687) or stainless steel (conforming to IS: 304) sheet (18G minimum) fixed in a frame work of rolled channel. The shutter shall consist of an insulating material like mineral wool in required thickness to satisfy the specified fire rating. Normally the thickness of door shutter shall not be less than 35mm for two hour fire rating and 46 mm for four hour fire rating.

The shutter with the required insulating material shall be mounted on angle iron frame or the special made frame from zinc coated (16G minimum) weldable steel sheet. The shutter shall be fixed to frame by means of suitable hinges and shall have a three way latching system. All the doors shall be provided with a coat of primer and one coat of synthetic enamel paint to attain the specified fire rating. All other accessories like hinges, door lock, hold fasts, etc. shall be provided as approved by TAC (Tariff Advisory Committee). All these accessories shall be compatible with the material used for door and shutter.

Annexure-3

Geotechnical Report

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Division of Soil Mechanics and Foundation Engineering
Department of Civil Engineering,
College of Engineering Guindy Campus,
Anna University, Chennai – 600 025. Ph: 044 22357549

PROGRESS THROUGH KNOWLEDGE

GEOTECHNICAL INVESTIGATION REPORT

NAME OF WORK : REPORT ON THE RECOMMENDATION OF FOUNDATION FOR THE PROPOSED CONSTRUCTION OF 400 MLD CAPACITY REVERSE OSMOSIS DESALINATION PLANT AT PERUR ON ECR, CHENNAI

CLIENT : **M/s AECOM India Pvt. Ltd., Gurgaon,**
9th Floor, Infinity Tower, 'C',
DLF Cyber City, DLF Phase II,
Gurgaon - 122002, Haryana

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JOB NO : SM&FE / 059 / Consultancy / MERIDIAN / 2014

DATE : 14th November 2014

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Division of Soil Mech. & Foundation Engg. CEGC Anna University Chennai-25

REPORT ON THE RECOMMENDATION OF FOUNDATION FOR THE PROPOSED CONSTRUCTION OF 400 MLD CAPACITY REVERSE OSMOSIS DESALINATION PLANT AT PERUR ON ECR, CHENNAI

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CLIENT:

M/s AECOM India Pvt. Ltd., Gurgaon,
9th Floor, Infinity Tower, 'C',
DLF Cyber City, DLF Phase II,
Gurgaon - 122002, Haryana

Ref: The Team Leader Lr. No. PMS / AU / LR / 053 Dated, 10.10.2014, From M/s Prime Meridian Surveys Pvt. Ltd

1. INTRODUCTION

The CMWSSB, Government of Tamilnadu has proposed to construct a 400 MLD capacity Reverse Osmosis Desalination Plant at Perur on ECR, Chennai. The CMWSSB has appointed M/s AECOM India Pvt. Ltd, Gurgaon, Haryana as consultant for this project. The officials of M/s AECOM India Pvt. Ltd, Gurgaon, Haryana and Engineers of CMWSSB, Chennai have approached the Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, Anna University, Chennai - 25 to carryout soil investigation in the proposed site and recommend the most suitable foundation system for the proposed construction of 400 MLD capacity Reverse Osmosis Desalination Plant. Accordingly, the work

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was taken up and Field Investigation was carried out by M/s VRR Engineering Consultancy, Chennai - 103 under the supervision of Professor, Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, Anna University, Chennai - 25. The soil investigation work was carried out during 28th of October 2014 to 5th of November 2014. This report comprises the details of soil investigation, analysis of field and laboratory test results and recommendation of most suitable foundation system.

2. SITE CONDITION AND EXPERIMENTAL PROGRAM

The proposed site is located at Perur, ECR, Chennai. The site is having ECR road to its western side and 200 m from bay of bengal sea shore to its eastern side. The site is covered with lot of trees. The water table was located within 1.5 m to 2.0 m as can be seen from many small ditches found in the site, because of nearness of seashore. The total number of borehole locations has been decided as 5 numbers as agreed by the client and the Professor & Project Co-ordinator, Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, Anna University, Chennai - 25. The location of bore hole is shown in figure 1. The nature of field tests includes standard penetration tests, disturbed soil sampling through split spoon sampler, identification of different soil layers, location of ground water table, complete logging of the borehole etc, Laboratory investigation consists of classification tests such as grain size distribution, Atterberg limits, specific gravity and free swell index of soil samples and point load strength index and geological classification of rock core samples.

After removing the top 0.25 m soil, the boreholes were advanced from the existing ground level using rotary boring technique supplemented by Bentonite mud circulation. Mud circulation was used to stabilize the sides and bottom of the boreholes and then to bring the soil

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3. REVIEW OF FIELD AND LABORATORY TEST RESULTS OF SOIL PROFILE

3.1 Borehole Number 1 (BH 1)

Brown sand layer was encountered at top 7.5 m depths with 'N' values of 11, 18, 28, 24, 27, 36 and 14 respectively for 1 m, 2 m, 3 m, 4 m, 5 m, 6 m and 7.5 m depths. The sand and fine content (silt and clay) of this sand layer is 91% - 98% and 2% - 9% respectively (Table 1). In 9 m and 10.5 m depths, brown sand layer was observed with 'N' values of 28 and 21 respectively. The sand and fine content (silt and clay) of this sand layer is 81% and 19% respectively. Grayish silty sand layer was found at 12 m depth with 'N' = 23 whose sand and fine (silt & clay) content values are 75% and 25% respectively. Grayish clayey sand (CI) of 'N' value 24 was found in 13.5 m depth. The sand and fine content (silt and clay) of this clayey sand layer is 43% and 57% respectively. This clayey sand (CI type) is having liquid limit of 42%, plastic limit of 22% and free swell index of 60% (Table 1). In 15 m depth, grayish silty clay (CH) layer was observed with 'N' value of 38 whose sand and fine content (silt and clay) value is 48% and 52%. This silty clay (CH type) is having liquid limit of 51% and plastic limit of 24%. Grayish clayey sand (SC-CH) of 'N' value > 100 (Hammer was Rebound for 55 blows with 13 cm penetration) was found in 16.5 m depth with sand and fine content (silt and clay) of 73% and 27% respectively. This clayey sand (SC - CI type) is having liquid limit of 41%, plastic limit of 22% and free swell index of 140%(Table 1). The high swelling nature and plasticity characteristics of this clayey sand is may be attributed to the presence of degraded Feldspar rock minerals of the underlying weathered rock layer. Grayish weathered rock was encountered in the depth range of 18 m to 20 m with SPT 'N' > 100 (Hammer was Rebound for 54 blows with 2 cm penetration at 18 m depth and 54 blows with 1 cm penetration at 19.5 m

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depth). The NX size double tube core barrel was used to drill and retrieve the rocky stratum from 20 m to 21.5 m depth. The observed rock layer is Pinkish Granite with more Feldspar mineral (Plate 5 and 9 of Annexure - 1). The weathering grade of this rock is II (slightly weathered and moderately strong) as per the ISI scale of weathering grade of rock mass. The Point Load Strength Index this pinkish granite is 1.18 MPa. The borehole was terminated at 21.5 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 1 in different depths are listed in table 1. The ground water table is located at a depth of 1.60 m from the existing ground level. Figure (a) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 1 location.

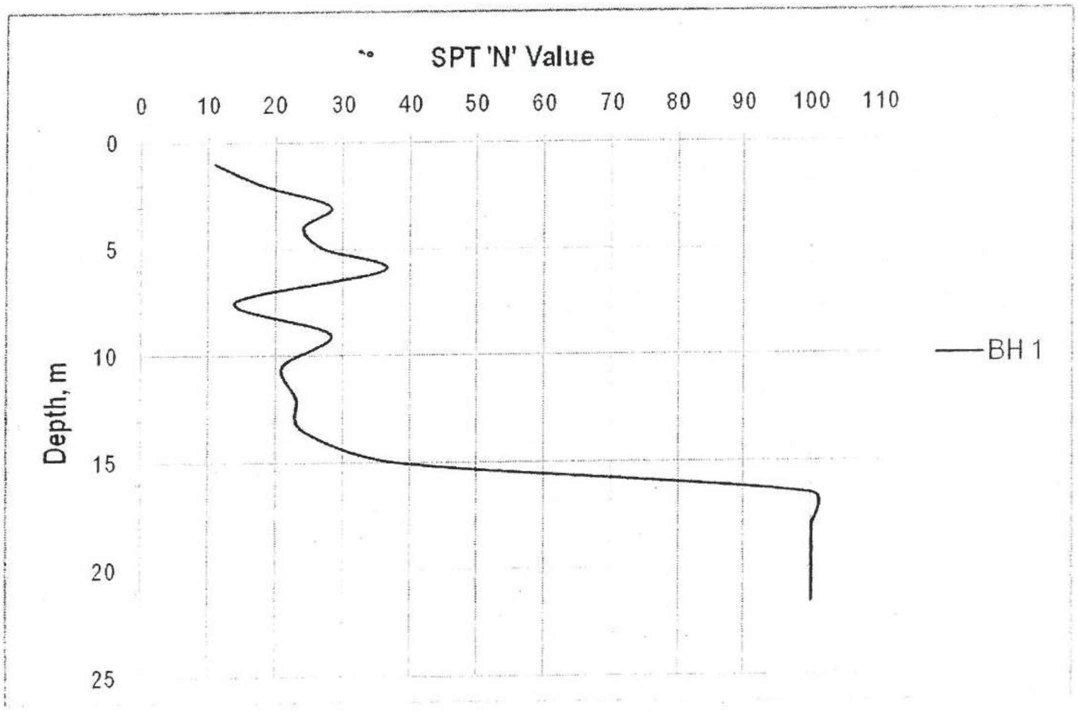

Figure (a) Variation of SPT 'N' value of different soil layers with respect to depth in BH 1

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3.2 Borehole Number 2 (BH 2)

In the top 9 m depth, brown sand layer was observed with 'N' values of 12, 18, 12, 33, 36, 40, 33 and 24 respectively for 1 m, 2 m, 3 m, 4 m, 5 m, 6 m, 7.5 m and 9 m depths. The sand and fine content (silt and clay) of this sand layer is 96% - 99% and 1% - 4% respectively. Grayish brown clayey sand (SC) of 'N' value 27 and 21 was found in 10.5 m and 12 m depths with sand and fine content (silt and clay) of 58%-65% and 35%-42% respectively. This clayey sand (SC type) is having liquid limit of 37%, plastic limit of 17% and free swell index of 40%(Table 2). Grayish silty clay (CI) of 'N' value 22 was encountered in 13.5 m depth. The sand and fine content (silt and clay) of this silty clay layer is 23% and 77% respectively. This silty sand (CI type) is having liquid limit of 44%, plastic limit of 25% and free swell index of 55%. In 15 m depth, grayish silty clay (CH) layer was observed with 'N' value of 36 whose sand and fine content (silt and clay) value is 23% and 77%. This silty clay (CH type) is having liquid limit of 57%, plastic limit of 24% and free swell index of 120% (Table 2). Grayish brown clayey sand (SC-CI) of 'N' = 38 was observed in 16.5 m depth with sand and fine content (silt and clay) of 54% and 46% respectively. This clayey sand (SC - CI type) is having liquid limit of 41%, plastic limit of 22% and free swell index of 100%(Table 2). The high swelling nature and plasticity characteristics of this clayey sand is may be due the presence of degraded rock minerals of the underlying weathered rock layer. Grayish weathered rock was encountered at 17.9 m with SPT 'N' > 100 (Hammer was Rebound for 54 blows with 2 cm penetration). The borehole was terminated at 17.9 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 2 in different depths are listed in table 2. The ground water table is located at a depth of 1.70 m from the existing ground level. Figure (b)

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shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 2 location.

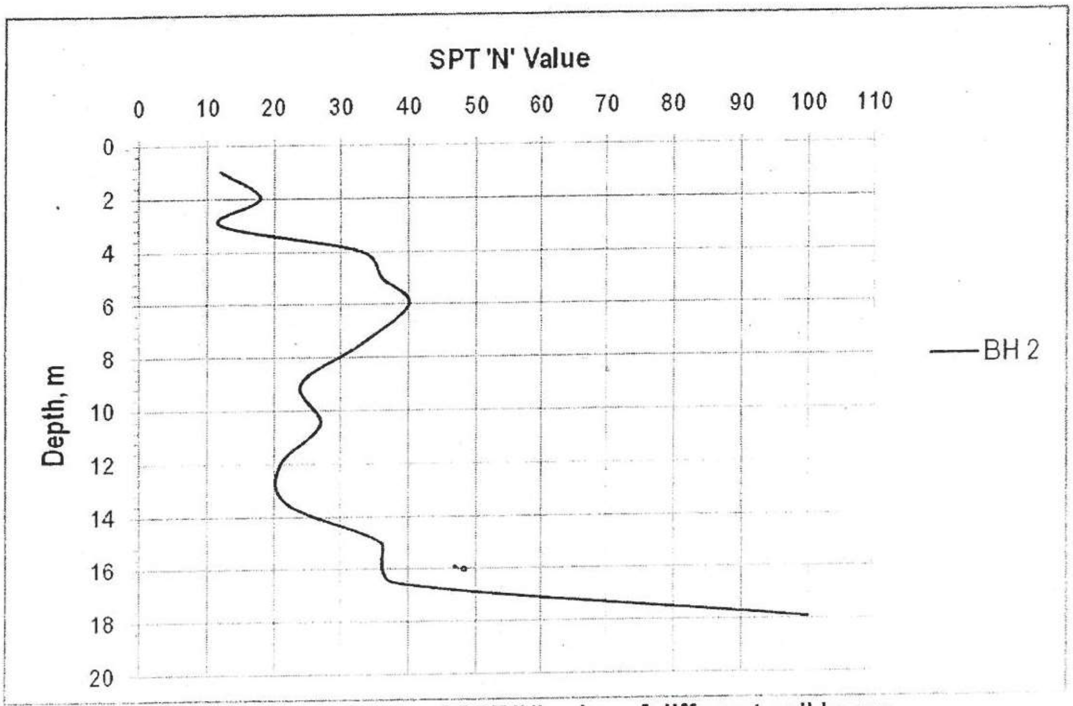

Figure (b) Variation of SPT 'N' value of different soil layers with respect to depth in BH 2

3.3 Borehole Number 3 (BH 3)

Brown sand layer was observed in top 6 m depths with 'N' values of 11, 12, 15, 18, 18 and 34 respectively for 1 m, 2 m, 3 m, 4 m, 5 m and 6 m depths. The sand and fine content (silt and clay) of this sand layer is 93% - 96% and 4% - 7% respectively (Table 3). In 7.5 m depth, grayish brown sand layer was observed with 'N' = 15. The sand and fine content (silt and clay) of this sand layer is 82% and 18% respectively. Grayish brown clayey sand (SC) of 'N' = 22 was found in 9 m depth with sand and fine content (silt and clay) of 67% and 33% respectively. This clayey sand (SC) is having liquid limit of 34%, plastic limit of 17% and free swell index of 40%(Table 3). At 10.5 m depth, grayish silty clay (CI) of 'N' value 23 was found with sand and

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fine content (silt and clay) of 43% and 57% respectively. This silty clay (CI type) is having liquid limit of 39%, plastic limit of 19% and free swell index of 45% (Table 3). In 12 m depth, grayish silty clay (CH) layer was observed with 'N' value of 22 whose sand and fine content (silt and clay) value is 26% and 74%. This silty clay (CH type) is having liquid limit of 47%, plastic limit of 23% and free swell index of 50%. Grayish clayey sand (SC-CI) of 'N' value 27 and 42 was found in 13.5 m and 15 m depths respectively with sand and fine content (silt and clay) of 62% and 38% respectively. This clayey sand (SC - CI type) is having liquid limit of 42%, plastic limit of 22% and free swell index of 50% (Table 3). The high swelling nature and plasticity characteristics of this clayey sand is may be attributed to the presence of degraded Feldspar rock minerals of the underlying weathered rock layer. Grayish weathered rock was encountered in the depth range of 16.5 m to 17 m with SPT 'N' > 100 (Hammer was Rebound for 57 blows with 8 cm penetration at 16.5 m depth and 55 blows with 3 cm penetration at 17 m depth). The NX size double tube core barrel was used to drill and retrieve the rocky stratum from 17 m to 18.5 m depth. The observed rock layer is Fresh Granite with more Hypersthene mineral (Plate 6 and 10 of Annexure - 1). The weathering grade of this rock is I (Fresh, no visible sign of weathering and very strong) as per the ISI scale of weathering grade of rock mass. The Point Load Strength Index this grayish granite is 2.20 MPa. The borehole was terminated at 18.5 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 3 in different depths are listed in table 3. The ground water table is located at a depth of 1.54 m from the existing ground level. Figure (c) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 3 location.

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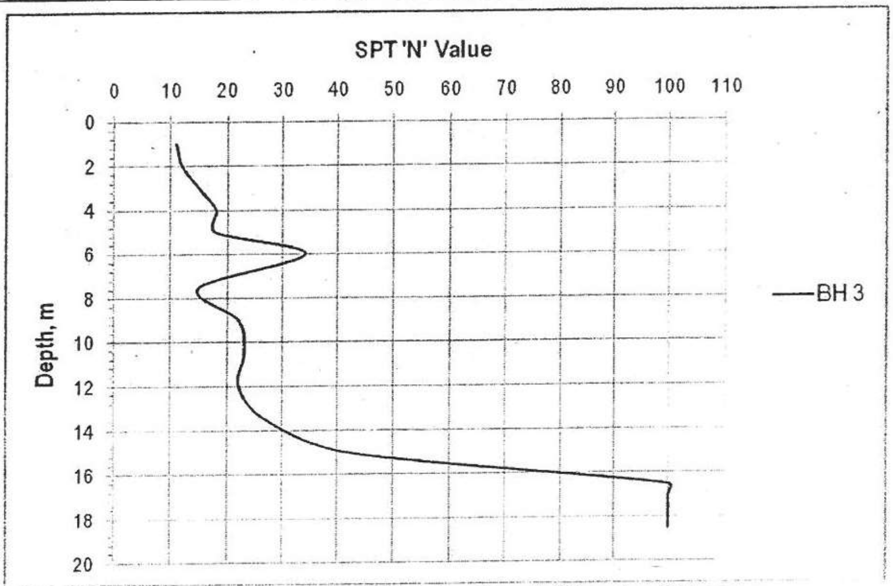

Figure (c) Variation of SPT 'N' value of different soil layers with respect to depth in BH 3

At 5 m, 6 m and 7.5 m depths, grayish brown sand layer was observed with 'N' values of 33, 36 and 18 respectively. The sand and fine content (silt and clay) of this sand layer is 83% - 89% and 11 - 17% respectively. Grayish brown clayey sand (SC) of 'N' = 24 was found in 9 m and 10.5 m depths with sand and fine content (silt and clay) of 70% and 30% respectively. This clayey sand (SC) is having liquid limit of 30%, plastic limit of 16% and free swell index of 30%(Table 4). In 12 m, 13.5 m and 15 m depths, grayish brown clayey sand (SC) of 'N' values 28, 58 and 67 was observed with sand and fine content (silt and clay) of 64% - 70% and 30% - 36% respectively. This clayey sand (SC type) is having liquid limit of 33%, plastic limit of 17% and free swell index of 40% (Table 4). Grayish weathered rock was encountered in the depth range of 16.5 m to 17 m with SPT 'N' > 100 (Hammer was Rebound for 55 blows with 5 cm penetration at 16.5 m depth and 53 blows with 2 cm penetration at 17 m depth). The NX size double tube core barrel was used to drill and retrieve the rocky stratum from 17 m to 18.5 m

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depth. The observed rock layer is Fresh Granite with more Hypersthene mineral (Plate 7 and 11 of Annexure - 1). The weathering grade of this rock is I to II (slightly weathering and moderately strong) as per the ISI scale of weathering grade of rock mass. The Point Load Strength Index this grayish granite is 1.10 MPa. The borehole was terminated at 18.5 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 4 in different depths are listed in table 4. The ground water table is located at a depth of 1.65 m from the existing ground level. Figure (d) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 4 location.

3.5 Borehole Number 5 (BH 5)

Brown sand layer was found in top 7.5 m depths with 'N' values of 14, 18, 35, 33, 36, 35 and 20 respectively for 1 m, 2 m, 3 m, 4 m, 5 m, 6 m and 7.5 m depths. The sand and fine content (silt and clay) of this sand layer is 86% - 96% and 4% - 14% respectively (Table 5). In 9 m and 10.5 m depths, brown clayey sand (SC) layer was observed with 'N' values of 27 and 22 respectively. The sand and fine content (silt and clay) of this clayey sand layer is 67% and 33% respectively. This clayey sand (SC) is having liquid limit of 30%, plastic limit of 16% and free swell index of 30% (Table 5). Grayish brown silty sand of 'N' = 54 and 72 was found in 12 m and 13.5 m depths with sand and fine content (silt and clay) of 85% and 15% respectively. In 15 m depth, grayish brown clayey sand (SC) of 'N' = 63 was observed with sand and fine content (silt and clay) of 60% and 40% respectively. This clayey sand (SC type) is having liquid limit of 34%, plastic limit of 17% and free swell index of 40% (Table 5). Grayish weathered rock was encountered in the depth range of 16.5 m to 19.6 m with SPT 'N' > 100 (Hammer was Rebound for 54 blows with 1 cm penetration at 16.5 m depth, 58 blows with 1 cm penetration at 18 m depth and 54 blows with 0 cm penetration at 19.6 m depth).

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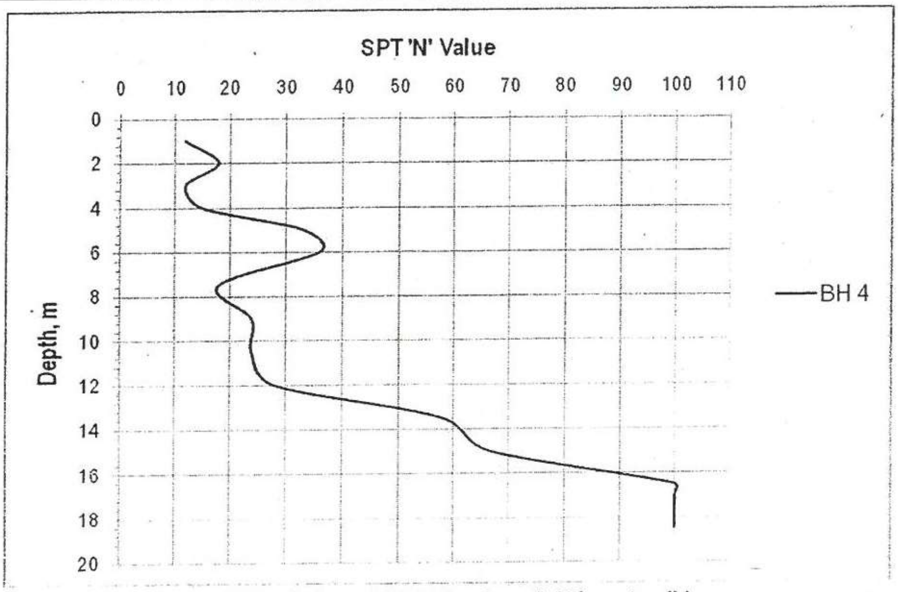

Figure (d) Variation of SPT 'N' value of different soil layers with respect to depth in BH 4

The NX size double tube core barrel was used to drill and retrieve the rocky stratum from 19.6 m to 21.1 m depth. The observed rock layer is Fresh Granite with more Hypersthene mineral (Plate 8 and 12 of Annexure - 1). The weathering grade of this rock is I (Fresh, no visible sign of weathering and very strong) as per the ISI scale of weathering grade of rock mass. The Point Load Strength Index this grayish granite is 1.78 MPa. The borehole was terminated at 18.5 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 5 in different depths are listed in table 5. The ground water table is located at a depth of 1.72 m from the existing ground level. Figure (e) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 5 location.

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Figure (f) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 1 to BH 5 of the proposed site. It is learnt that ground water level might raise to as high as 0.5 m to 1.5 m to 2 m normal water table fluctuation, especially during winter season.

4.0 COMPUTATION OF BEARING CAPACITY AND SETTLEMENT

In order to determine the bearing capacity and settlement of the '*shallow open foundation system*' at various depths of 2.0 m and 3.0 m depths, the location of ground water table is assumed at ground surface (submerged condition). Table I to Table V show the SPT'N' value, Correlated CPT 'q_c' value (IS 2911, Part 1, Sec.1), Correlated Elastic Modulus 'E_s' value (Schmertmann 1970) and Shear strength parameters of the borehole 1 to 5 of the proposed site. The geotechnical design parameters of engineering properties of soil layers which are required to determine bearing capacity and settlement are taken from Table I to Table V by considering the worst soil condition and least shear strength parameters below the foundation depth. The least 'N' values of soil layers were observed in BH - 3. Hence, safe bearing capacity and settlement computations were made for BH-3 data. The Safe Bearing Capacity is computed using Bureau of Indian Standard IS 6403-1981 equation. The Settlement of foundation is arrived based De Beer Method (IS 8009 (Part I) 1976 Sec. 9.1.2) using the correlated CPT 'q_c' value (IS 2911, Part 1, Sec.1), of the borehole number 3 of the proposed site.

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Figure (f) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 1 to BH 5 of the proposed site. It is learnt that ground water level might raise to as high as 0.5 m to 1.5 m to 2 m normal water table fluctuation, especially during winter season.

4.0 COMPUTATION OF BEARING CAPACITY AND SETTLEMENT

In order to determine the bearing capacity and settlement of the *'shallow open foundation system'* at various depths of 2.0 m and 3.0 m depths, the location of ground water table is assumed at ground surface (submerged condition). Table I to Table V show the SPT'N' value, Correlated CPT 'q_c' value (IS 2911, Part 1, Sec.1), Correlated Elastic Modulus 'E_s' value (Schmertmann 1970) and Shear strength parameters of the borehole 1 to 5 of the proposed site. The geotechnical design parameters of engineering properties of soil layers which are required to determine bearing capacity and settlement are taken from Table I to Table V by considering the worst soil condition and least shear strength parameters below the foundation depth. The least 'N' values of soil layers were observed in BH - 3. Hence, safe bearing capacity and settlement computations were made for BH-3 data. The Safe Bearing Capacity is computed using Bureau of Indian Standard IS 6403-1981 equation. The Settlement of foundation is arrived based De Beer Method (IS 8009 (Part I) 1976 Sec. 9.1.2) using the correlated CPT 'q_c' value (IS 2911, Part 1, Sec.1), of the borehole number 3 of the proposed site.

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TABLE I SPT "N" values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 1 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m^2)	Elastic Modulus 'E_s' Value (kN/m^2)	Shear Strength Parameters	
				'c' (kN/m^2)	Φ in Degrees
1.0	11	4400	8426	0	29^0
2.0	18	7200	13788	0	33^0
3.0	28	11200	21448	0	37^0
4.0	24	9600	18384	0	35^0
5.0	27	10800	20682	0	37^0
6.0	36	14400	27576	0	40^0
7.5	14	5600	10724	0	30^0
9.0	28	11200	21448	0	37^0
10.5	21	8400	16086	0	34^0
12.0	23	6900	17618	0	35^0
13.5	24	4800	18384	150	0^0
15.0	38	7600	29108	237	0^0
16.5	> 100	40000	76600	0	45^0
18.0	> 100	100000	76600	0	45^0
19.5	> 100	100000	76600	0	45^0
20 - 21.5	> 100	Point Load Strength Index = 1.18 MPa			

TABLE II SPT "N" values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 2 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m^2)	Elastic Modulus 'E_s' Value (kN/m^2)	Shear Strength Parameters	
				'c' (kN/m^2)	Φ in Degrees
1.0	12	4800	9192	0	29^0
2.0	18	7200	13788	0	33^0
3.0	12	4800	9192	0	29^0
4.0	33	13200	25278	0	39^0
5.0	36	14400	27576	0	40^0
6.0	40	16000	30640	0	42^0
7.5	33	13200	25278	0	39^0
9.0	24	9600	18384	0	35^0

TABLE I SPT "N" values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 1 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m^2)	Elastic Modulus 'E_s' Value (kN/m^2)	Shear Strength Parameters	
				'c' (kN/m^2)	Φ in Degrees
1.0	11	4400	8426	0	29^0
2.0	18	7200	13788	0	33^0
3.0	28	11200	21448	0	37^0
4.0	24	9600	18384	0	35^0
5.0	27	10800	20682	0	37^0
6.0	36	14400	27576	0	40^0
7.5	14	5600	10724	0	30^0
9.0	28	11200	21448	0	37^0
10.5	21	8400	16086	0	34^0
12.0	23	6900	17618	0	35^0
13.5	24	4800	18384	150	0^0
15.0	38	7600	29108	237	0^0
16.5	> 100	40000	76600	0	45^0
18.0	> 100	100000	76600	0	45^0
19.5	> 100	100000	76600	0	45^0
20 - 21.5	> 100	Point Load Strength Index = 1.18 MPa			

TABLE II SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 2 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m^2)	Elastic Modulus 'E_s' Value (kN/m^2)	Shear Strength Parameters	
				'c' (kN/m^2)	Φ in Degrees
1.0	12	4800	9192	0	29^0
2.0	18	7200	13788	0	33^0
3.0	12	4800	9192	0	29^0
4.0	33	13200	25278	0	39^0
5.0	36	14400	27576	0	40^0
6.0	40	16000	30640	0	42^0
7.5	33	13200	25278	0	39^0
9.0	24	9600	18384	0	35^0

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10.5	27	8100	20682	0	37^0
12.0	21	6300	16086	0	34^0
13.5	22	4400	16852	137	0^0
15.0	36	7200	27576	225	0^0
16.5	38	15200	29108	0	41^0
17.9	> 100	100000	76600	0	45^0

TABLE III SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 3 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m^2)	Elastic Modulus 'E_s' Value (kN/m^2)	Shear Strength Parameters	
				'c' (kN/m^2)	Φ in Degrees
1.0	11	4400	8426	0	29^0
2.0	12	4800	9192	0	29^0
3.0	15	6000	11490	0	31^0
4.0	18	7200	13788	0	33^0
5.0	18	7200	13788	0	33^0
6.0	34	13600	26044	0	39^0
7.5	15	6000	11490	0	31^0
9.0	22	6600	16852	0	35^0
10.5	23	4600	17618	143	0^0
12.0	22	4400	16852	137	0^0
13.5	27	8100	20682	0	37^0
15.0	42	12600	32172	0	42^0
16.5	> 100	100000	76600	0	45^0
17.0	> 100	100000	76600	0	45^0
17 - 18.5	> 100	Point Load Strength Index = 2.20 MPa			

TABLE IV SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 4 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m^2)	Elastic Modulus 'E_s' Value (kN/m^2)	Shear Strength Parameters	
				'c' (kN/m^2)	Φ in Degrees
1.0	12	4800	9192	0	29^0
2.0	18	7200	13788	0	33^0
3.0	12	4800	9192	0	29^0

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10.5	27	8100	20682	0	37^0
12.0	21	6300	16086	0	34^0
13.5	22	4400	16852	137	0^0
15.0	36	7200	27576	225	0^0
16.5	38	15200	29108	0	41^0
17.9	> 100	100000	76600	0	45^0

TABLE III SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 3 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	11	4400	8426	0	29^0
2.0	12	4800	9192	0	29^0
3.0	15	6000	11490	0	31^0
4.0	18	7200	13788	0	33^0
5.0	18	7200	13788	0	33^0
6.0	34	13600	26044	0	39^0
7.5	15	6000	11490	0	31^0
9.0	22	6600	16852	0	35^0
10.5	23	4600	17618	143	0^0
12.0	22	4400	16852	137	0^0
13.5	27	8100	20682	0	37^0
15.0	42	12600	32172	0	42^0
16.5	> 100	100000	76600	0	45^0
17.0	> 100	100000	76600	0	45^0
17 - 18.5	> 100	Point Load Strength Index = 2.20 MPa			

TABLE IV SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 4 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	12	4800	9192	0	29^0
2.0	18	7200	13788	0	33^0
3.0	12	4800	9192	0	29^0

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4.0	15	6000	11490	0	31⁰
5.0	33	13200	25278	0	39⁰
6.0	36	14400	27576	0	40⁰
7.5	18	7200	13788	0	33⁰
9.0	24	7200	18384	0	35⁰
10.5	24	7200	18384	0	35⁰
12.0	28	8400	21448	0	37⁰
13.5	58	17400	44428	0	45⁰
15.0	67	20100	51322	0	45⁰
16.5	> 100	100000	76600	0	45⁰
17.0	> 100	100000	76600	0	45⁰
17 - 18.5	> 100	Point Load Strength Index = 1.10 MPa			

TABLE V SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 5 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	14	5600	10724	0	30⁰
2.0	18	7200	13788	0	33⁰
3.0	35	14000	26810	0	40⁰
4.0	33	13200	25278	0	39⁰
5.0	36	14400	27576	0	40⁰
6.0	35	14000	26810	0	40⁰
7.5	20	8000	15320	0	34⁰
9.0	27	8100	20682	0	37⁰
10.5	22	6600	16852	0	35⁰
12.0	54	16200	41364	0	45⁰
13.5	72	28800	55152	0	45⁰
15.0	63	18900	48258	0	45⁰
16.5	> 100	100000	76600	0	45⁰
18.0	> 100	100000	76600	0	45⁰
19.6	> 100	100000	76600	0	45⁰
19.6 - 21.1	> 100	Point Load Strength Index = 1.78 MPa			

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4.1 Allowable Bearing Capacity

The average design 'N' value and shear strength parameters below foundation level up to the influence depth of 1B is used to determine the Safe Bearing Capacity. The Safe Bearing Capacity is computed using Bureau of Indian Standard IS 6403-1981 equation. The width of foundation is assumed as 2.5 m to determine the Safe Bearing Capacity for varying depth of foundation. The computed Safe Bearing Capacity for the proposed site is shown in Table VI.

TABLE VI Safe Bearing Capacity of the proposed Site at Perur, ECR, Chennai for 2.5 m width of Foundation

Depth of Foundation (m)	Design Shear Strength Parameters		Safe Bearing Capacity (kN/m²) IS 6403-1981 Equation
	'c' (kN/m²)	Φ in Degrees	
2.0	0	30^0	158
2.5	0	31^0	209
3.0	0	32^0	274

4.2 Settlement of Soil Layer

One of the important aspects of any foundation systems is to satisfy the settlement criteria apart from bearing capacity criteria. The total settlement of foundation is becoming very critical, especially if the foundation is located on clays, because the clay layer is expected to undergo excessive consolidation settlement over a period of time under sustained loadings which of course depends on the state of clay (initial water content / void ratio), whereas in the

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case of loose sand layer, elastic or immediate settlement plays a crucial role. The Table VII shows the settlement of foundation computed based on De Beer Method (S 8009 (Part I) 1976 Sec. 9.1.2) with respect to safe bearing capacity of the 2.5 m x 2.5 m foundation at various depths. The settlement is computed up to the influence depth of "2B" below the foundation. ***The allowable settlement as per IS 1904 Table I 1986 is 50 mm.***

TABLE VII Settlement Values computed with Respect to the Safe Bearing Capacity of 2.5 m x 2.5 m Size Foundation

Size of Foundation	Depth of Foundation	Safe Bearing Capacity (kN/m^2)	Settlement as per De Beer Method - IS 8009 (Part I) 1976 Sec. 9.1.2 (mm)
2.5 m x 2.5 m	2.0 m	158	17.99
	2.5 m	209	20.99
	3.0 m	274	26.62

5.0 DETERMINATION OF SAFE PILE CARRYING CAPACITY

As the exact total structural load of the super structure has not been made available to this office of Division of Soil Mechanics and Foundation Engineering, CEG, Anna University, Chennai - 25, attempts are also made to suggest pile foundation for varying pile diameter apart from recommendation of shallow foundation. For computing the load carrying capacity of pile, Indian Standard IS 2911 (Part 1/Sec. 2) 2010 method and Meyerhof 1959 formula (Based on SPT 'N' Value) is used. The diameters of piles are assumed as 400 mm, 500 mm, 600 mm and 750 mm and the length of the pile is taken as 17 m to 20 m. The least shear strength parameters and least 'N' values were taken as the criteria from Table I to Table V out of the five borehole locations for the design of pile foundation for the proposed site. Accordingly, the least shear strength parameters and least 'N' values of soil layers were observed in BH - 3. Hence, safe pile carrying capacity computations were made for BH-3 borehole data. The Indian Standard IS 2911 (2010) specifies that the base resistance should not exceed 1000 to 1100 t/m^2 for bored cast-in-situ piles and 1500 t/m^2 for precast driven piles. The end bearing capacity is also computed based on Cole and Stroud (1977) approach by providing 0.5 D in Granite Rock Strata as pile socketing (D is pile diameter in mm). The shear strength of rocky stratum (point bearing shear strength) is the point load strength index of the rock samples which is used to determine the ultimate end bearing resistance of the pile.

For calculating the skin friction along the pile length of 17 m to 20 m, the design 'N' values and shear strength parameters for respective depths were used. As seen from section 3.5, the water table may fluctuate significantly varying from 0.5 m to 2 m because of nearness of seashore. This instant fluctuations may induce settlement of surrounding soil which in turn may cause negative skin friction. Hence, the safe frictional capacity were computed beyond 2 m depth. The safe end bearing capacity and safe skin frictional capacity are together added for different pile diameter and the total safe load carrying capacity of pile thus computed is shown in Table VIII. The factor of safety of 3 has been used for determining safe end bearing and also frictional capacity of bored cast-in-situ piles.

The uplift capacity of a pile is given by sum of the frictional resistance and the weight of the pile (buoyant or total as relevant) as per Section 6.3.2 of IS 2911 (Part 1/Sec. 2) 2010. The recommended factor of safety is 3.0 in the absence of any pull out test results and 2.0 with pullout test results. Uplift capacity can be obtained from static formula by ignoring end-bearing

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but adding weight of the pile (buoyant or total as relevant). The safe uplift capacity of pile varying diameter is given in Table IX.

TABLE VIII Safe Load Carrying Capacity of Pile for varying Diameter for the Length of 17 m to 20 m

Pile Diameter	Safe Pile Capacity (Tons) Meyerhof 1959	Safe Pile Capacity (Tons) (IS 2911 Part-I 2010 Static Formula)	Safe Pile Capacity (Tons) Cole and Stroud (1977) Formula) - 0.5 D Socketed into Granite Rock Strata
400 mm	79	87	90
500 mm	95	104	107
600 mm	129	140	145
750 mm	191	204	213

TABLE IX Safe Uplift Capacity of Pile for varying Diameter for the Length of 17 m to 20 m(IS 2911 (Part 1/Sec. 2) 2010

Pile Diameter	Safe Uplift Capacity (Tons) IS 2911 (Part 1/Sec. 2) 2010
400 mm	41
500 mm	47
600 mm	58
750 mm	76

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6. CONCLUSIONS

Upon Consideration and closer examination of the discussions of section 4 and 5, the following conclusions are made for the proposed construction of 400 MLD capacity Reverse Osmosis Desalination Plant at Perur on ECR, Chennai.

✓ The recommended safe bearing capacity of the proposed site for '*shallow foundation*' is shown in Table X for varying depth. The minimum width of foundation shall be 2.5 m.

Table X Recommended Safe Bearing Capacity of the proposed site at Perur, ECR, Chennai

Size of Foundation	Depth of Foundation	Safe Bearing Capacity (kN/m^2)	Settlement as per De Beer Method - IS 8009 (Part I) 1976 Sec. 9.1.2 (mm)
2.5 m x 2.5 m	2.0 m	158	17.99
	2.5 m	209	20.99
	3.0 m	274	26.62

✓ As an alternative to the shallow foundation, the recommended safe vertical pile carrying capacity and uplift capacity of the 17 m to 20 m length of 'bored cast in-situ pile' for varying diameter is shown in Table XI.

✓ The bored cast in-situ pile shall be terminated at about 17 m to 20 m depth on the rocky stratum.

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Table XI Recommended Safe Load Carrying Capacity and Uplift Capacity of Pile for varying Diameter for the Length of 17 m at Perur, ECR, Chennai

Pile Diameter	Pile Capacity (Tons)	Uplift Capacity (Tons)
400 mm	86	41
500 mm	102	47
600 mm	138	58
750 mm	203	76

- ✓ Pile load test has to be conducted to ensure the designed pile carrying capacity. The minimum grade of concrete for pile foundation is M25.

- ✓ Because of the proximity of seashore to the proposed site, there is every possibility for sea water intrusion during open excavation, if shallow foundation is proposed. Enough care may be taken to design a suitable dewatering system while construction of foundation is in progress.

14/11/14

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REFERENCES

[1] SP 36 Part I: 1987, "Laboratory Testing on Soil for Civil Engineering Purpose", Compendium on Indian Standards on Soil Engineering, Bureau of Indian Standards.

[2] SP 36 Part II: 1988, "Field Testing of Soils for Civil Engineering Purpose", Compendium on Indian Standards on Soil Engineering, Bureau of Indian Standards.

[3] IS 6403-1981 (Reaffirmed 1997), "Code of Practice for Determination of Bearing Capacity of Shallow Foundations", Bureau of Indian Standards.

[4] IS 8009 (Part I) (Reaffirmed 1998), "Code of Practice for Calculation of Settlements of Foundations", Bureau of Indian Standards.

[5] IS 2911, Part 1 (2010),"Code of Practice for Design and Construction of Pile Foundations", Bureau of Indian Standards.

[6] IS 1904 - 1986 (Reaffirmed 1995)," Code of Practice for Design and Construction of Foundations in Soils : General Requirements", Bureau of Indian Standards.

[7] Schmertmann, J.H. 1970. "Static cone to compute static settlement over sand", Journal of the Soil Mechanics and Foundations Division, ASCE, 96(3): 1011-1043.

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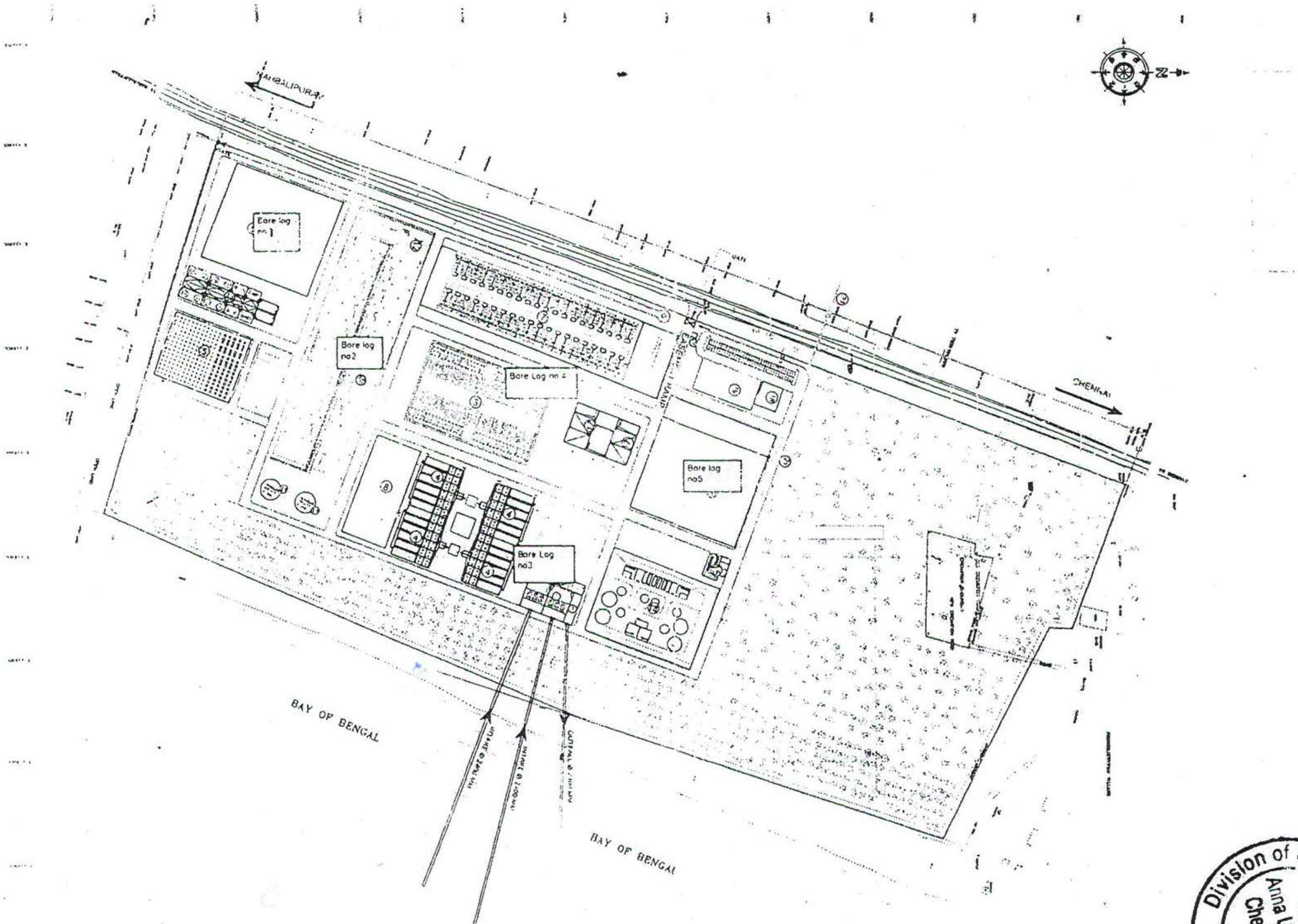

Figure 1 Location of Boreholes

LIST OF UNITS

1. INLET ONSHORE SCREENS
2. INTAKE PUMP STATION
3. OUTFALL CHAMBER
4. LAMELLA CLARIFIER
5. PRE TREATMENT STORAGE
6. DISSOLVED AIR FLOATATION
7. DUAL MEDIA GRAVITY FILTER
8. RO FEED TANK
9. ELECTRICAL SUBSTATION
10. RO BUILDING
11. RO PERMEATE TANK
12. CIP
13. CHEMICAL STORAGE FOR RO
14. POTABILIZATION
15. POST-CHLORINATION BUILDING
16. PRODUCT WATER TANK
17. FILTER BW HOLDING TANK
18. ADMINISTRATION BUILDING
19. MAINTENANCE WORKSHOP
20. GUARD HOUSE
21. PRODUCT WATER MAIN

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CONSULTANT	CLIENT		
AECOM WATEK AECOM INDIA Private Limited in Association with GHD Pty Limited and WATEK Engineering	Chennai Metro Water Supply and Sewerage Board	PROJECT TITLE -	CONSULTANCY TO CONDUCT PREFEASIBILITY STUDIES INCLUDING FINANCIAL VIABILITY PREPARATION OF DETAILED PROJECT REPORT BID SETTING UP OF 400 MLD CAPACITY SEA WATER REVERSE OSMOSIS DESALINATION PLANTS FOR CHENNAI CITY ALONG ECR ROAD CHENNAI TAMILNADU INDIA
		DRAWING TITLE -	LAYOUT
		SCALE - AS SHOWN	DWG. NO. 12138CMWSSB/SWRO/001 — SIZE A3

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FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH NO	1	DATE OF START	03.11.2014
SITE	Perur	DATE OF COMPLETION	04.11.2014
DIA OF BORING	150 mm	GROUND WATER LEVEL	1.60 m
TYPE OF BORING	Rotary (Calyx)	RL	-

Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling				Relative Density/ Consistency
			15	30	45	N	
1.00		Brown Sand	3	5	6	11	Medium Dense
2.00		Brown Sand	6	7	11	18	Medium Dense
3.00		Brown Sand	10	10	18	28	Medium Dense
4.00		Brown Sand	9	10	14	24	Medium Dense
5.00		Brown Sand	10	12	15	27	Medium Dense
6.00		Brown Sand	12	18	18	36	Medium Dense
7.50		Brown Sand	9	7	7	14	Medium Dense
9.00		Brown Sand	11	13	15	28	Medium Dense
10.5		Brown Sand	8	10	11	21	Medium Dense
12.0		Grayish Silty Sand	9	11	12	23	Medium Dense
13.5		Grayish Clayey Sand	8	12	12	24	Medium Dense
15.0		Brown Silty Clay	11	18	20	38	Hard
16.5		Grayish Brown Clayey Sand	21	55 (13 cm) Rebound		> 100	Hard
18.0		Grayish Brown Weathered Rock	54 (2 cm) Hammer Rebound			> 100	Hard
19.5		Grayish Brown Weathered Rock	54 (1 cm) Hammer Rebound			> 100	Hard
20 - 21.5		Pinkish Gray Granite Rock	CR = 60%, RQD = 20%			> 100	Hard

Borehole Termination Depth is 21.5 m from the Existing Ground Level

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Figure 2

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FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH NO	2	DATE OF START	01.11.2014
SITE	Perur	DATE OF COMPLETION	02.11.2014
DIA OF BORING	150 mm	GROUND WATER LEVEL	1.70 m
TYPE OF BORING	Rotary (Calyx)	RL	-

Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling				Relative Density/ Consistency
			15	30	45	N	
1.00		Brown Sand	4	6	6	12	Medium Dense
2.00		Brown Sand	6	8	10	18	Medium Dense
3.00		Brown Sand	3	6	6	12	Medium Dense
4.00		Brown Sand	6	15	18	33	Dense
5.00		Brown Sand	15	18	18	36	Dense
6.00		Brown Sand	17	18	22	40	Dense
7.50		Brown Sand	13	15	18	33	Dense
9.00		Brown Sand	11	11	13	24	Medium Dense
10.5		Grayish Brown Clayey Sand	12	13	14	27	Medium Dense
12.0		Grayish Brown Clayey Sand	9	10	11	21	Medium Dense
13.5		Grayish Silty Clay	10	11	11	22	Very Stiff
15.0		Grayish Silty Clay	9	18	18	36	Very Stiff
16.5		Grayish Brown Clayey Sand	11	15	23	38	Dense
17.9		Grayish Brown Weathered Rock	54 (2 cm) Hammer Rebound			> 100	Hard

Borehole Termination Depth is 17.9 m from the Existing Ground Level

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Figure 3

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FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH NO	3	DATE OF START	05.11.2014
SITE	Perur	DATE OF COMPLETION	05.11.2014
DIA OF BORING	150 mm	GROUND WATER LEVEL	1.54 m
TYPE OF BORING	Rotary (Calyx)	RL	-

Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling 15	30	45	N	Relative Density/ Consistency
1.00		Brown Sand	2	5	6	11	Medium Dense
2.00		Brown Sand	3	6	6	12	Medium Dense
3.00		Brown Sand	4	7	8	15	Medium Dense
4.00		Brown Sand	5	8	10	18	Medium Dense
5.00		Brown Sand	6	8	10	18	Medium Dense
6.00		Brown Sand	11	15	19	34	Dense
7.50		Grayish Brown Sand	7	7	8	15	Medium Dense
9.00		Grayish Brown Clayey Sand	7	11	11	22	Medium Dense
10.5		Grayish Silty Clay	7	11	12	23	Very Stiff
12.0		Grayish Silty Clay	8	10	12	22	Very Stiff
13.5		Grayish Brown Clayey Sand	9	10	17	27	Medium Dense
15.0		Grayish Brown Clayey Sand	11	18	24	42	Dense
16.5		Grayish Brown Weathered Rock	57 (8 cm) Hammer Rebound			> 100	Hard
17.0		Grayish Brown Weathered Rock	55 (3 cm) Hammer Rebound			> 100	Hard
18.5		Grayish Granite Rock	CR = 25%, RQD = 7%			> 100	Hard

Borehole Termination Depth is 18.5 m from the Existing Ground Level

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Figure 4

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FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH NO	4	DATE OF START	30.10.2014
SITE	Perur	DATE OF COMPLETION	31.10.2014
DIA OF BORING	150 mm	GROUND WATER LEVEL	1.65 m
TYPE OF BORING	Rotary (Calyx)	RL	-

Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling				Relative Density/ Consistency
			15	30	45	N	
1.00		Brown Sand	5	5	7	12	Medium Dense
2.00		Brown Sand	6	9	9	18	Medium Dense
3.00		Brown Sand	4	6	6	12	Medium Dense
4.00		Brown Sand	6	7	8	15	Medium Dense
5.00		Grayish Brown Sand	8	12	21	33	Medium Dense
6.00		Grayish Brown Sand	9	16	20	36	Dense
7.50		Grayish Brown Sand	6	8	10	18	Medium Dense
9.00		Grayish Brown Clayey Sand	8	11	13	24	Medium Dense
10.5		Grayish Brown Clayey Sand	9	12	12	24	Very Stiff
12.0		Grayish Brown Clayey Sand	10	12	16	28	Very Stiff
13.5		Grayish Brown Clayey Sand	16	25	33	58	Very Dense
15.0		Grayish Brown Clayey Sand	17	33	34	67	Very Dense
16.5		Grayish Brown Weathered Rock	55 (5 cm) Hammer Rebound			> 100	Hard
17.0		Grayish Brown Weathered Rock	53 (2 cm) Hammer Rebound			> 100	Hard
18.5		Grayish Granite Rock	CR = 20%, RQD = 7%			> 100	Hard
Borehole Termination Depth is 18.5 m from the Existing Ground Level							

Figure 5

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FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH NO	5	DATE OF START	28.10.2014
SITE	Perur	DATE OF COMPLETION	30.10.2014
DIA OF BORING	150 mm	GROUND WATER LEVEL	1.72 m
TYPE OF BORING	Rotary (Calyx)	RL	-

Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling				Relative Density/ Consistency
			15	30	45	N	
1.00		Brown Sand	4	7	7	14	Medium Dense
2.00		Brown Sand	5	8	10	18	Medium Dense
3.00		Brown Sand	10	14	21	35	Dense
4.00		Brown Sand	11	15	18	33	Dense
5.00		Brown Sand	12	18	18	36	Dense
6.00		Brown Sand	12	15	20	35	Dense
7.50		Brown Sand	6	10	10	20	Medium Dense
9.00		Brown Clayey Sand	9	12	15	27	Medium Dense
10.5		Brown Clayey Sand	8	10	12	22	Medium Dense
12.0		Grayish Brown Silty Sand	18	23	31	54	Very Dense
13.5		Grayish Brown Silty Sand	20	30	42	72	Very Dense
15.0		Grayish Brown Clayey Sand	21	30	33	63	Very Dense
16.5		Grayish Brown Weathered Rock	54 (1 cm) Hammer Rebound			> 100	Hard
18.0		Grayish Brown Weathered Rock	58 (1 cm) Hammer Rebound			> 100	Hard
19.6		Grayish Brown Weathered Rock	54 (0 cm) Hammer Rebound			> 100	Hard
19.6 - 21.1		Grayish Granite Rock	CR = 20%, RQD = 0%			> 100	Hard
Borehole Termination Depth is 21.1 m from the Existing Ground Level							

Figure 6

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Table 1

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH 1 | Ground Water Level | 1.60 m from EGL

LABORATORY TEST RESULTS

SPT 'N' Value	Depth (m)	Soil Description / Classification	Index Properties						Specific Gravity	Grain Size Analysis (%)						~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
			Natural Moisture Content (NMC), %	Bulk Density (kN/m³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines		Cohesion (c) kN/m²	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm²/sec	Compressibility Index, (C_c)
														Silt	Clay				
11	1.00	Brown Sand	19	18	Non Plastic				2.63	0	3	40	55	2		0	29^0	-	-
18	2.00	Brown Sand	15	19	Non Plastic				2.63	0	4	34	56	6		0	33^0	-	-
28	3.00	Brown Sand	13	21	Non Plastic				2.64	0	3	31	62	4		0	37^0	-	-
24	4.00	Brown Sand	19	20	Non Plastic				2.63	0	2	21	72	5		0	35^0	-	-
27	5.00	Brown Sand	19	21	Non Plastic				2.64	0	2	22	71	5		0	37^0	-	-
36	6.00	Brown Sand	20	22	Non Plastic				2.62	0	3	14	80	3		0	40^0	-	-
14	7.50	Brown Sand	14	18	Non Plastic				2.63	0	15	39	37	9		0	30^0	-	-
28	9.00	Brown Sand	12	21	Non Plastic				2.62	0	42	24	15	19		0	37^0	-	-
21	10.5	Brown Sand	17	20	Non Plastic				2.62	0	12	14	55	19		0	34^0	-	-
23	12.0	Grayish Silty Sand	20	20	Non Plastic				2.66	0	0	4	71	25		0	35^0	-	-
24	13.5	Grayish Clayey Sand (CI)	15	20	42	22	20	45	2.60	0	4	11	28	57		150	0^0	-	-
38	15.0	Brown Silty Clay (CH)	17	22	51	24	27	60	2.60	0	7	11	30	52		237	0^0	-	-
> 100	16.5	Grayish Clayey Sand (SC - CI)	14	22	41	22	19	140	2.67	2	21	23	27	27		0	45^0	-	-
> 100	18.0	Grayish Brown Weathered Rock	Washed Sample													0	45^0	-	-
> 100	19.5	Grayish Brown Weathered Rock	Washed Sample													0	45^0		

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974).

Table 2

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR																			
BH 2														Ground Water Level		1.70 m from EGL			
LABORATORY TEST RESULTS																			
			Index Properties							Grain Size Analysis (%)				Fines		~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
SPT 'N' Value	Depth (m)	Soil Description / Classification	Natural Moisture Content (NMC), %	Bulk Density (kN/m^3)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index	Specific Gravity	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt	Clay	Cohesion (c) kN/m^2	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm^2/sec	Compressibility Index, (C_c)
12	1.00	Brown Sand	16	18	Non Plastic				2.64	0	5	44	49	2		0	29^0	-	-
18	2.00	Brown Sand	16	19	Non Plastic				2.64	0	3	48	47	2		0	33^0	-	-
12	3.00	Brown Sand	17	18	Non Plastic				2.63	0	0	25	73	2		0	29^0	-	-
33	4.00	Brown Sand	17	22	Non Plastic				2.64	0	7	18	71	4		0	39^0	-	-
36	5.00	Brown Sand	18	22	Non Plastic				2.63	0	30	39	27	4		0	40^0	-	-
40	6.00	Brown Sand	18	22	Non Plastic				2.63	0	31	40	28	1		0	42^0	-	-
33	7.50	Brown Sand	17	22	Non Plastic				2.62	0	28	41	30	1		0	39^0	-	-
24	9.00	Brown Sand	13	20	Non Plastic				2.61	0	20	29	34	17		0	35^0	-	-
27	10.5	Grayish Brown Clayey Sand (SC)	12	21	37	17	20	40	2.60	0	17	18	30	35		0	37^0	-	-
21	12.0	Grayish Brown Clayey Sand (SC)	21	20	37	17	20	40	2.60	0	9	8	41	42		0	34^0	-	-
22	13.5	Grayish Silty Clay (CI)	21	20	44	25	19	55	2.66	0	0	2	21	77		137	0^0	-	-
36	15.0	Grayish Silty Clay (CH)	19	22	57	24	33	120	2.66	0	0	2	21	77		225	0^0	-	-
38	16.5	Grayish Brown Clayey Sand (SC - CI)	17	22	41	22	19	100	2.67	0	10	11	33	46		0	41^0		
> 100	17.9	Grayish Brown Weathered Rock	Washed Sample													0	45^0		

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974).

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Table 3

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH 3 | Ground Water Level | 1.54 m from EGL

LABORATORY TEST RESULTS

SPT 'N' Value	Depth (m)	Soil Description / Classification	Index Properties						Specific Gravity	Grain Size Analysis (%)					~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
			Natural Moisture Content (NMC), %	Bulk Density (kN/m³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines (Silt / Clay)	Cohesion (c) kN/m²	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm²/sec	Compressibility Index, (C_c)
11	1.00	Brown Sand	20	18	Non Plastic				2.62	0	3	45	46	6	0	29°	-	-
12	2.00	Brown Sand	23	18	Non Plastic				2.62	0	2	36	58	4	0	29°	-	-
15	3.00	Brown Sand	22	19	Non Plastic				2.63	0	2	35	58	5	0	31°	-	-
18	4.00	Brown Sand	19	19	Non Plastic				2.63	0	0	47	49	4	0	33°	-	-
18	5.00	Brown Sand	19	19	Non Plastic				2.64	0	2	43	48	7	0	33°	-	-
34	6.00	Brown Sand	19	22	Non Plastic				2.62	0	47	13	35	5	0	39°	-	-
15	7.50	Grayish Brown Sand	12	19	Non Plastic				2.64	0	29	23	30	18	0	31°	-	-
22	9.00	Grayish Brown Clayey Sand (SC)	12	20	34	17	17	40	2.63	0	7	22	38	33	0	35°	-	-
23	10.5	Grayish Silty Clay (CI)	19	20	39	19	20	45	2.61	0	0	0	43	57	143	0°	-	-
22	12.0	Grayish Silty Clay (CH)	19	20	47	23	24	50	2.61	0	0	0	26	74	137	0°	-	-
27	13.5	Grayish Brown Clayey Sand (SC - CI)	13	21	42	22	20	50	2.65	0	23	14	25	38	0	37°	-	-
42	15.0	Grayish Brown Clayey Sand (SC - CI)	15	22	42	22	20	50	2.65	0	32	8	22	38	0	42°	-	-
> 100	16.5	Grayish Brown Weathered Rock	Washed Sample												0	45°	-	-
> 100	17.0	Grayish Brown Weathered Rock	Washed Sample												0	45°	-	-

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974).

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Table 4

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH 4 | **Ground Water Level** | **1.65 m from EGL**

LABORATORY TEST RESULTS

SPT 'N' Value	Depth (m)	Soil Description / Classification	Index Properties						Specific Gravity	Grain Size Analysis (%)						~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
			Natural Moisture Content (NMC), %	Bulk Density (kN/m³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines		Cohesion (c) kN/m²	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm²/sec	Compressibility Index, (C_c)
														Silt	Clay				
12	1.00	Brown Sand	15	18	Non Plastic				2.63	0	0	32	59	9		0	29^0	-	-
18	2.00	Brown Sand	16	19	Non Plastic				2.64	0	0	25	64	11		0	33^0	-	-
12	3.00	Brown Sand	18	18	Non Plastic				2.64	0	0	18	71	11		0	29^0	-	-
15	4.00	Brown Sand	16	19	Non Plastic				2.64	0	3	28	58	11		0	31^0	-	-
33	5.00	Grayish Brown Sand	14	22	Non Plastic				2.63	0	3	28	58	11		0	39^0	-	-
36	6.00	Grayish Brown Sand	16	22	Non Plastic				2.63	0	5	25	59	11		0	40^0	-	-
18	7.50	Grayish Brown Sand	11	19	Non Plastic				2.63	0	2	39	42	17		0	33^0	-	-
24	9.00	Grayish Brown Clayey Sand (SC)	11	20	30	16	14	30	2.66	0	0	7	63	30		0	35^0	-	-
24	10.5	Grayish Brown Clayey Sand (SC)	11	20	30	16	14	30	2.66	0	0	10	60	30		0	35^0	-	-
28	12.0	Grayish Brown Clayey Sand (SC)	12	21	33	17	16	40	2.66	0	0	9	61	30		0	37^0	-	-
58	13.5	Grayish Brown Clayey Sand (SC)	12	22	33	17	16	40	2.68	0	2	14	51	33		0	45^0	-	-
67	15.0	Grayish Brown Clayey Sand (SC)	12	22	33	17	16	40	2.68	0	1	20	43	36		0	45^0	-	-
> 100	16.5	Grayish Brown Weathered Rock	Washed Sample													0	45^0	-	-
> 100	17.0	Grayish Brown Weathered Rock	Washed Sample													0	45^0	-	-

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974).

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Table 5

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH 5 — Ground Water Level: 1.72 m from EGL

LABORATORY TEST RESULTS

SPT 'N' Value	Depth (m)	Soil Description / Classification	Index Properties						Specific Gravity	Grain Size Analysis (%)						~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
			Natural Moisture Content (NMC), %	Bulk Density (kN/m³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines		Cohesion (c) kN/m²	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm²/sec	Compressibility Index, (C_c)
														Silt	Clay				
14	1.00	Brown Sand	15	18	Non Plastic				2.64	0	0	7	84	9		0	30^0	-	-
18	2.00	Brown Sand	15	19	Non Plastic				2.63	0	0	23	68	9		0	33^0	-	-
35	3.00	Brown Sand	18	22	Non Plastic				2.63	0	11	30	50	9		0	40^0	-	-
33	4.00	Brown Sand	18	22	Non Plastic				2.64	0	0	4	90	6		0	39^0	-	-
36	5.00	Brown Sand	18	22	Non Plastic				2.64	0	0	9	87	4		0	40^0	-	-
35	6.00	Brown Sand	13	22	Non Plastic				2.64	0	0	11	85	4		0	40^0	-	-
20	7.50	Brown Sand	13	20	Non Plastic				2.64	0	6	26	54	14		0	34^0	-	-
27	9.00	Brown Clayey Sand (SC)	14	21	30	16	14	30	2.62	0	7	28	42	33		0	37^0	-	-
22	10.5	Brown Clayey Sand (SC)	14	20	30	16	14	30	2.62	0	7	28	42	33		0	35^0	-	-
54	12.0	Grayish Brown Silty Sand	14	22	Non Plastic				2.66	0	1	30	54	15		0	45^0	-	-
72	13.5	Grayish Brown Silty Sand	14	22	Non Plastic				2.66	0	1	30	54	15		0	45^0	-	-
63	15.0	Grayish Brown Clayey Sand (SC)	12	22	34	17	17	40	2.60	0	2	21	37	40		0	45^0	-	-
> 100	16.5	Grayish Brown Weathered Rock	Washed Sample													0	45^0	-	
> 100	18.0	Grayish Brown Weathered Rock	Washed Sample													0	45^0		
> 100	19.6	Grayish Brown Weathered Rock	Washed Sample													0	45^0		

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974)

Executive Engineer (Desal)
Chennai Metropolitan Water Supply & Sewerage Board
Chennai - 600 002.

Division of Soil Mech. & Foundation Engg.
CEGC
Anna University
Chennai-25

Annexure - 1 (Site Photographs)

Division of Soil Mech. & Foundation Engg.
CEGC
Anna University
Chennai-25

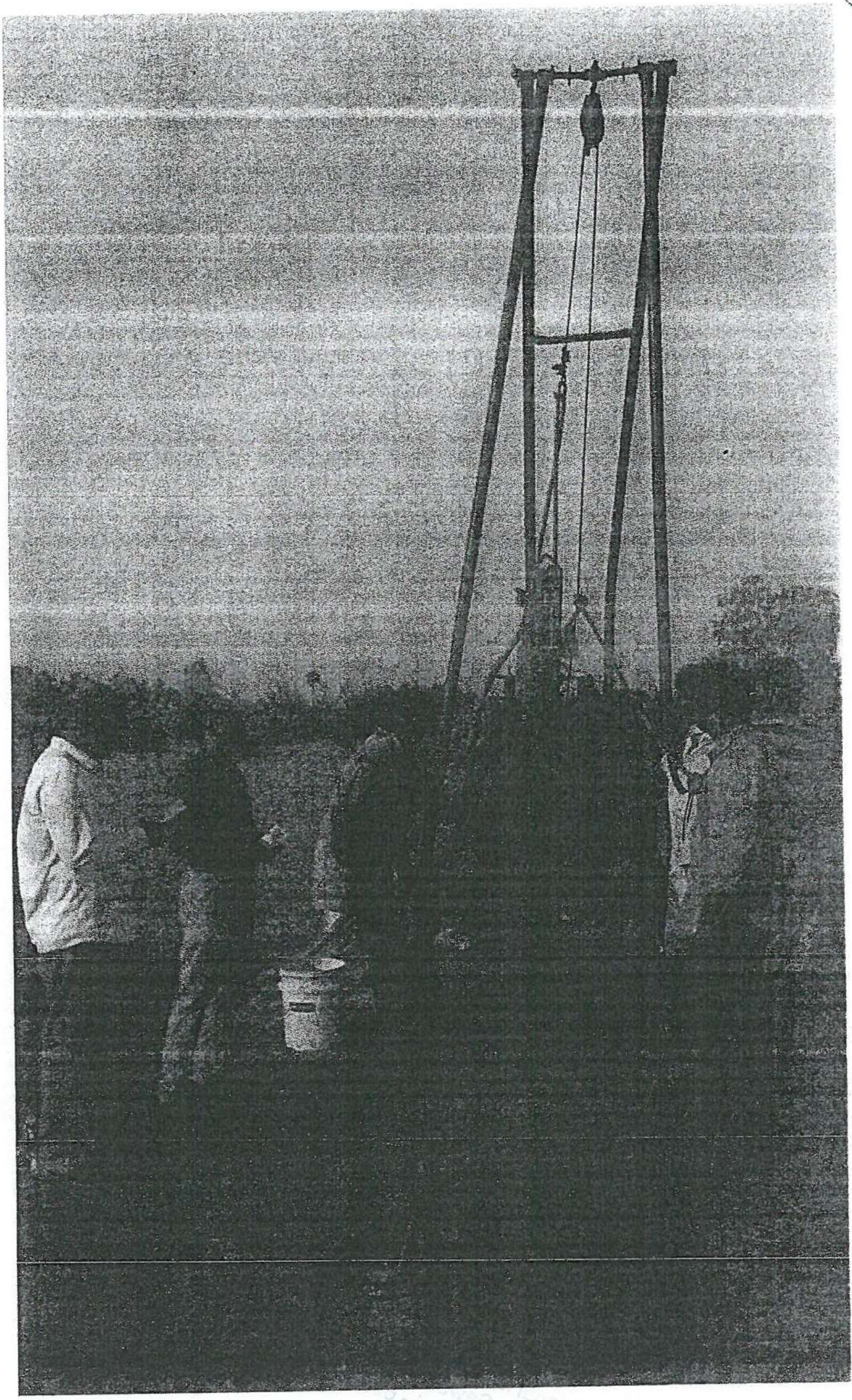
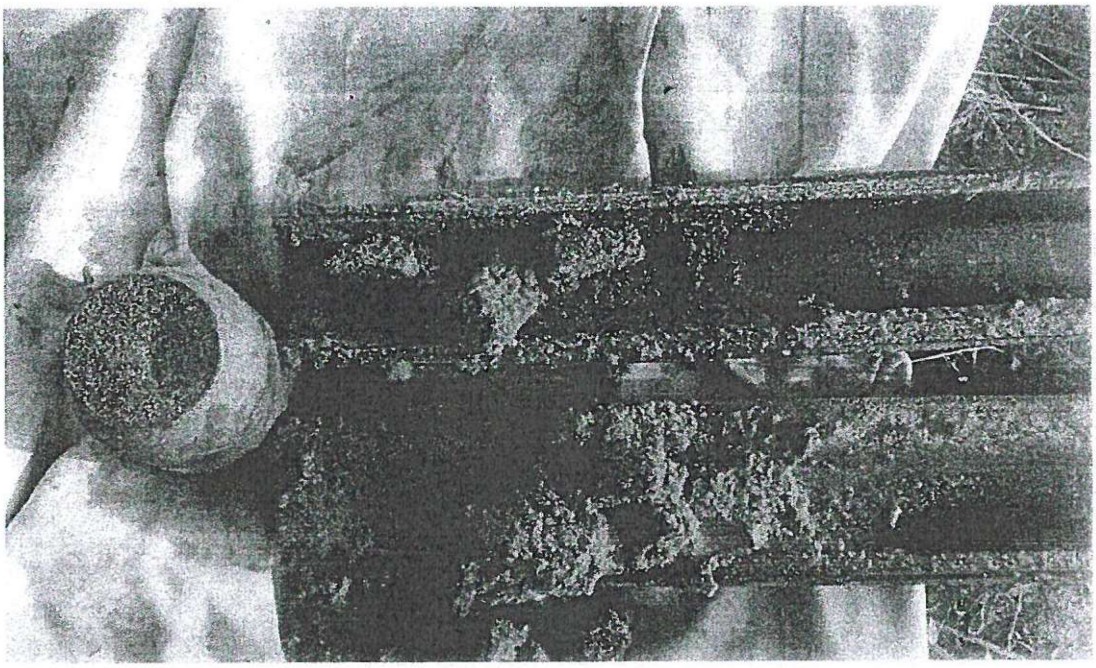


Plate 1 View of SPT in Progress at the proposed Site

Executive Engineer (Desal)
Chennai Metropolitan Water Supply &
Sewerage Board
Chennai - 600 002.

Division of Soil Mech. & Foundation Engg.
CEGC
Anna University
Chennai-25



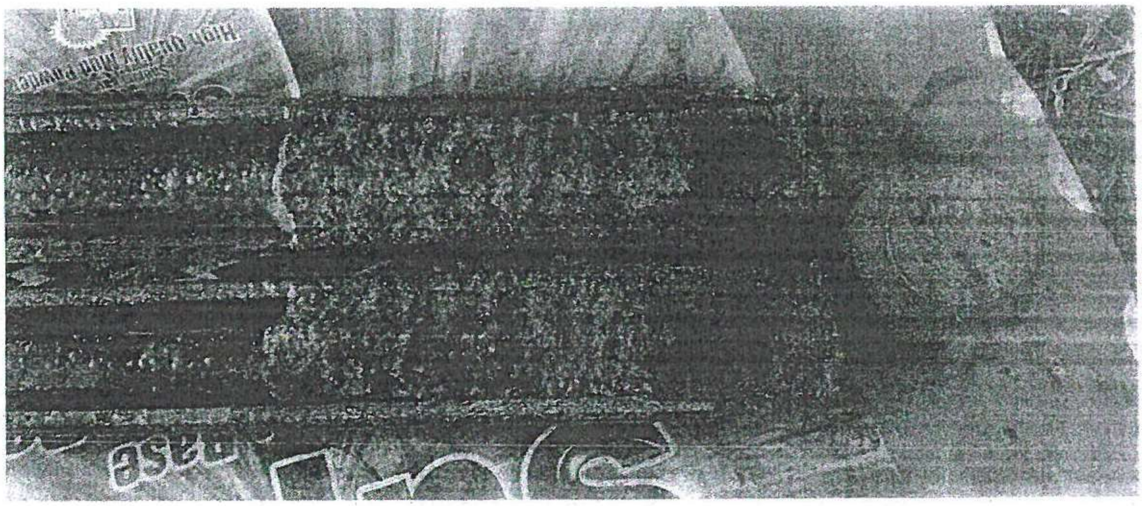


Plate 2 View of Soil Sampling through Split Spoon Sampler at the proposed Site

Executive Engineer (Desal)
Chennai Metropolitan Water Supply &
Sewerage Board
Chennai - 600 002.

Plate 3 Inspection by the Faculty Member of Department of Civil Engineering, CEG, Anna University, Chennai - 25 on 01.11.2014 at proposed Site

Plate 4 Inspection by the Faculty Member of Department of Civil Engineering, CEG, Anna University, Chennai - 25 on 01.11.2014 at proposed Site

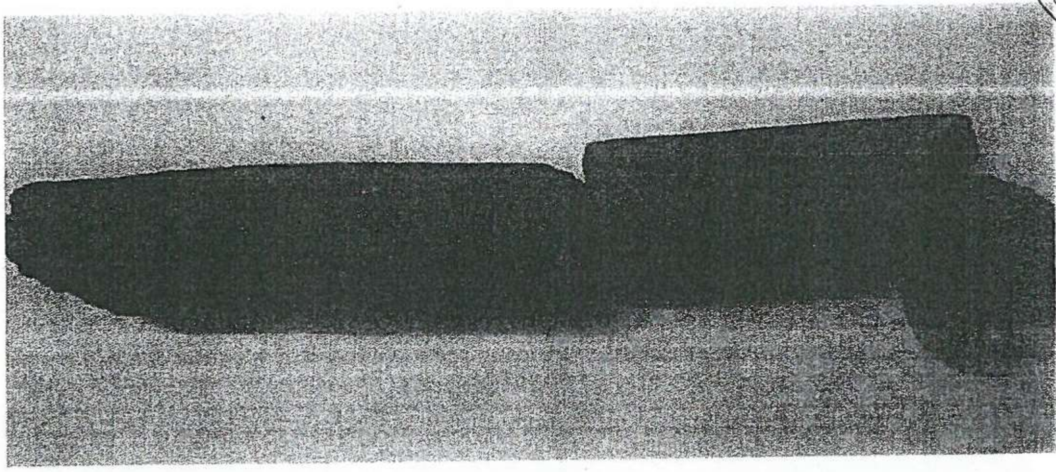


Plate 5 View of Pinkish Granite Core Sample found at BH 1 in 20.0 to 21.5 m Depth

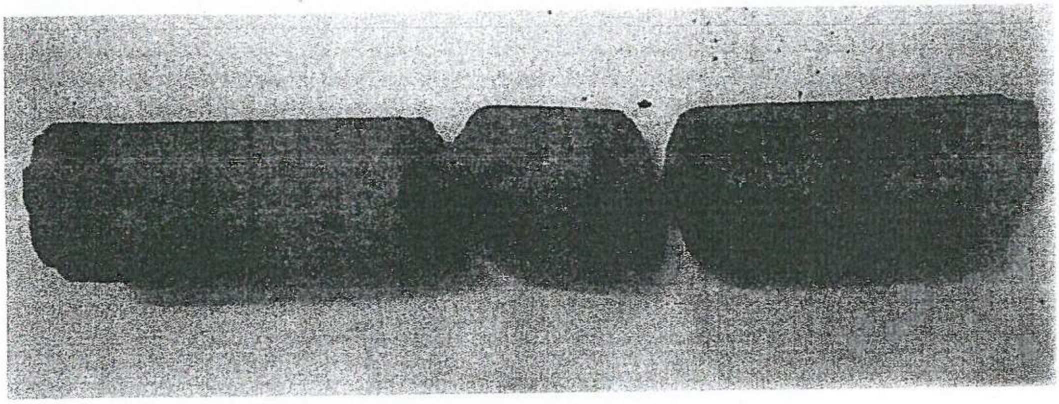


Plate 6 View of Grayish Granite Core Sample found at BH 3 in 17.0 to 18.5 m Depth

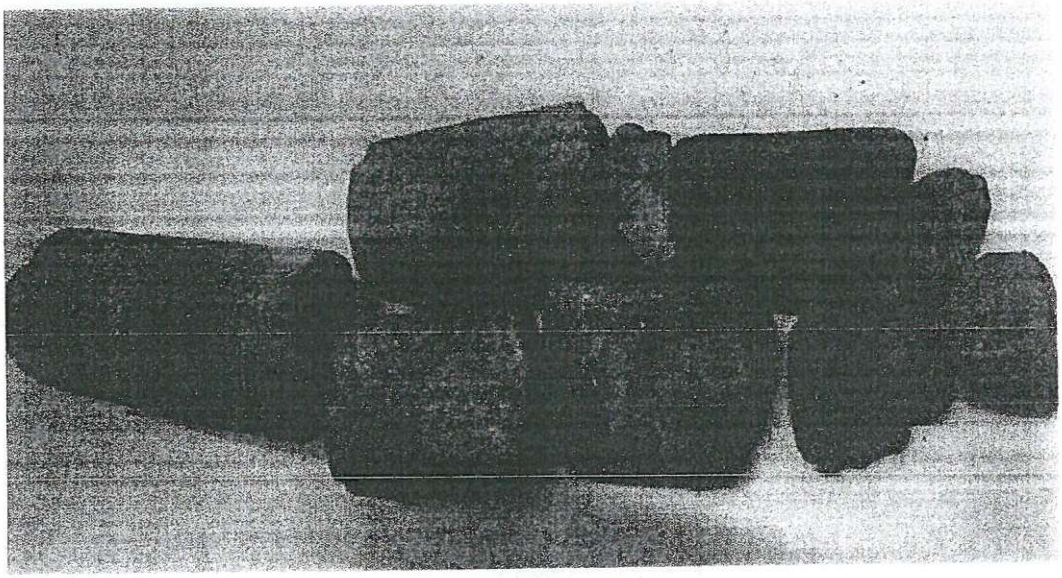


Plate 7 View of Grayish Granite Core Sample found at BH 4 in 17.0 to 18.5 m Depth

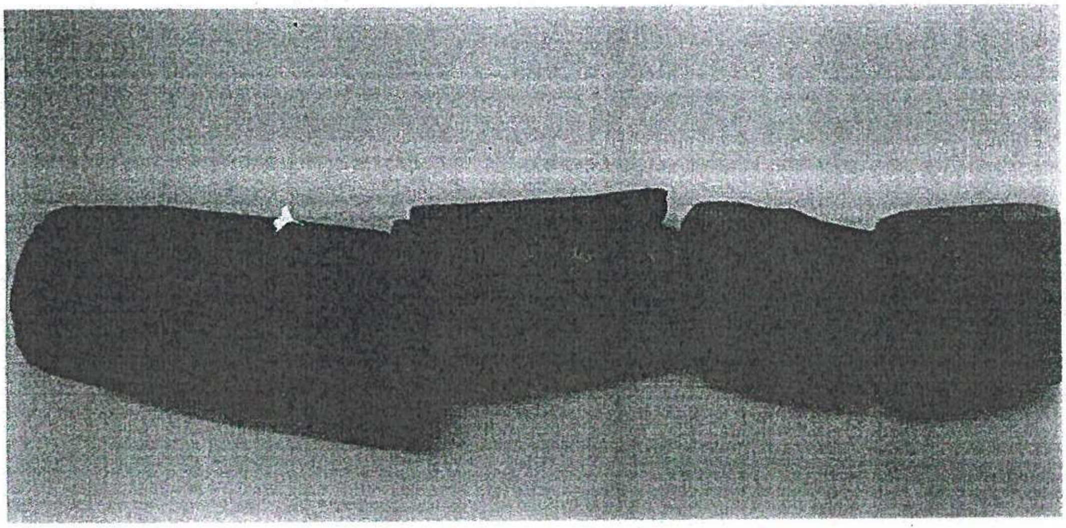


Plate 8 View of Grayish Granite Core Sample found at BH 5 in 19.6 to 21.1 m Depth

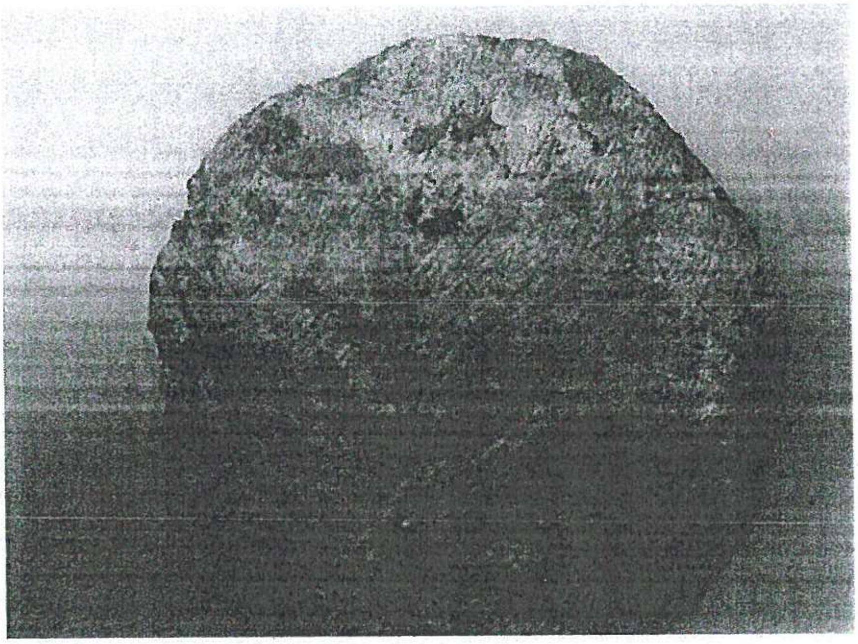


Plate 9 Texture of Pinkish Granite core sample at BH 1 in 20.0 to 21.5 m Depth

CEGC
Anna University
Chennai-25
Division of Foundation Engg.

Plate 10 Texture of Grayish Granite core sample at BH 3 in 17.0 to 18.5 m Depth

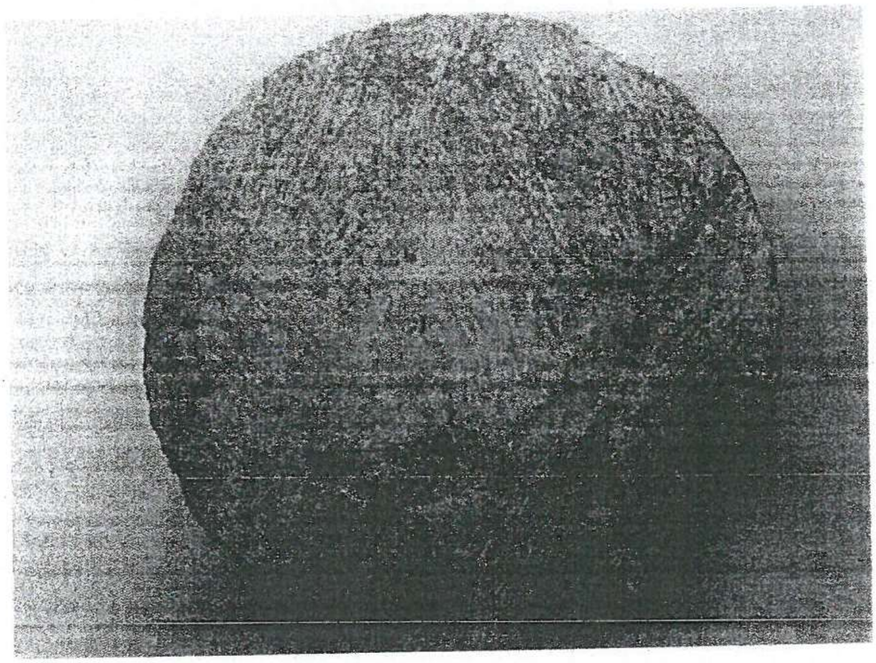


Plate 11 Texture of Grayish Granite core sample at BH 4 in 17.0 to 18.5 m Depth

Executive Engineer (Desal)
Chennai Metropolitan Water Supply &
Sewerage Board
Chennai - 600 002.

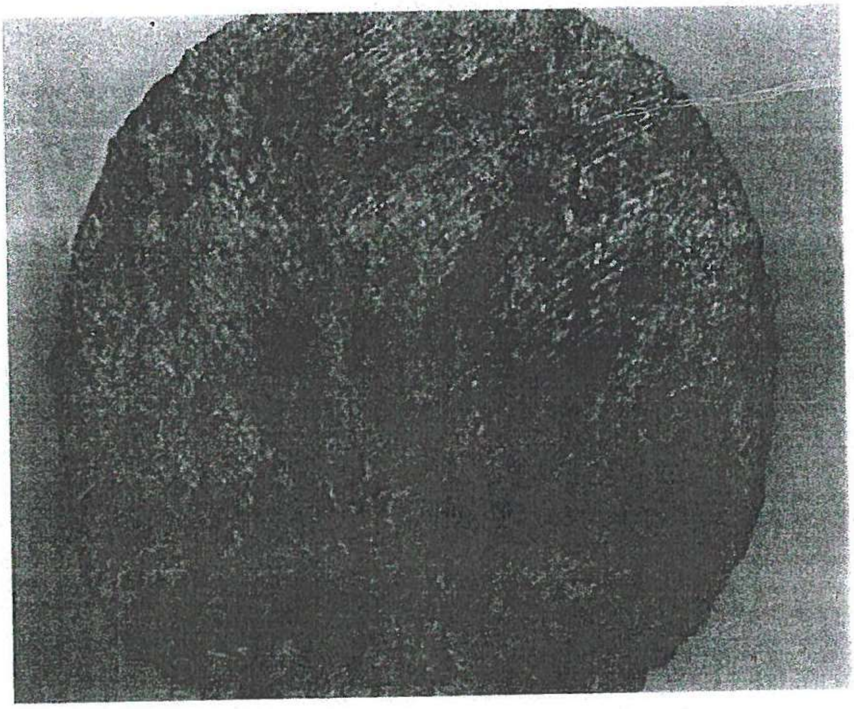


Plate 12 Texture of Grayish Granite at BH 5 core sample in 19.6 to 21.1 m Depth

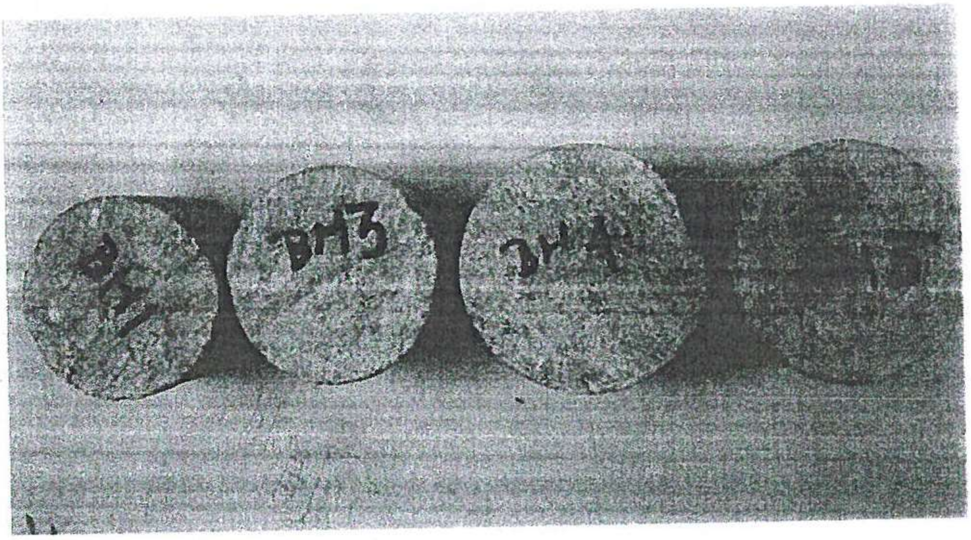
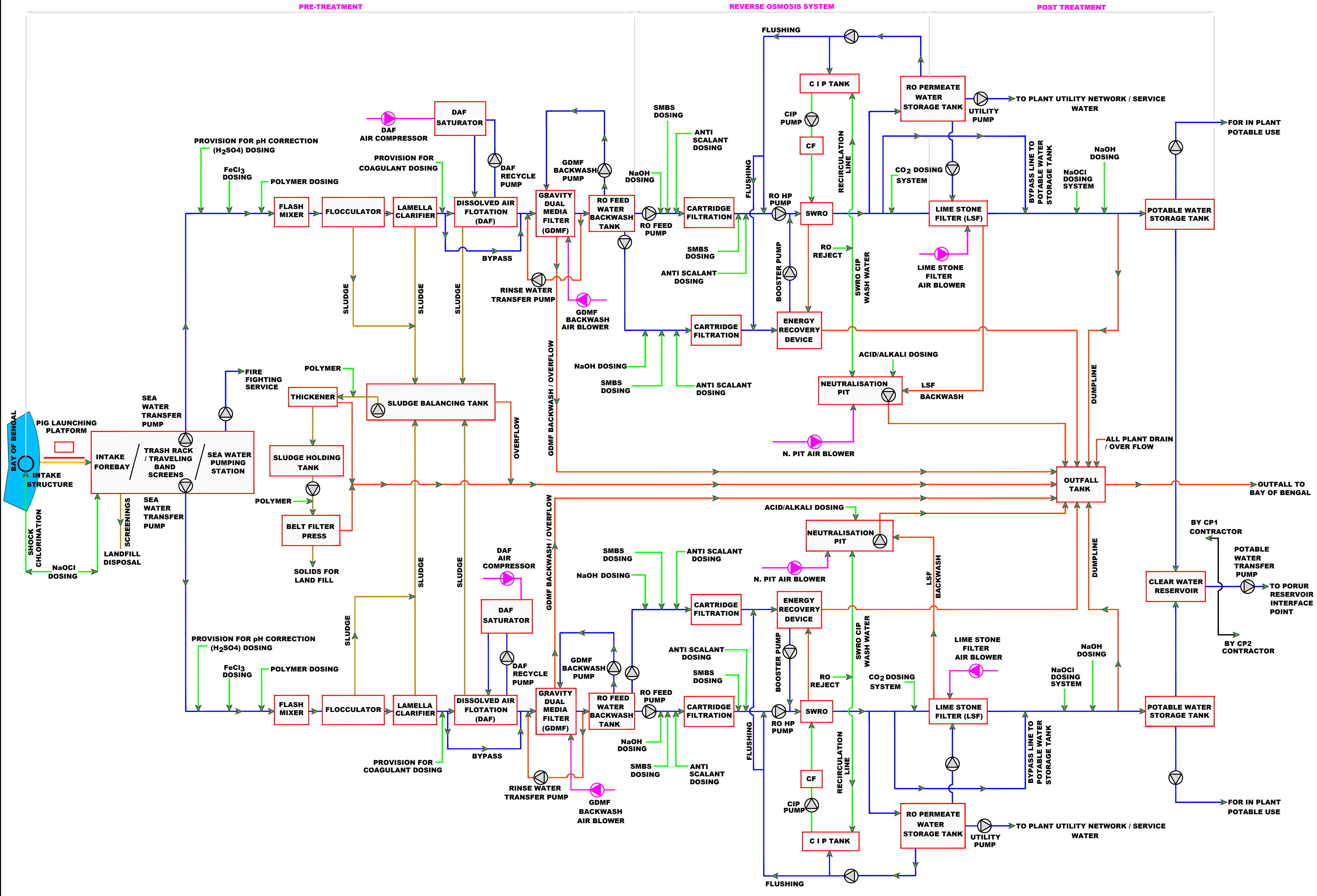


Plate 13 View of Rock Core Samples prepared for conducting Point Load Strength Index Test in Department of Civil Engineering, CEG, Anna University, Chennai - 25



NOTES:

1. TWO (2) STREAMS EACH OF 200 MLD CAPACITY PROPOSED.
2. SEAWATER PUMPING STATION, POTABLE WATER STORAGE TANK, SLUDGE BALANCING TANK, THICKENER, SLUDGE HOLDING TANK, BELT FILTER PRESS BUILDING ARE COMMON UNITS FOR BOTH STREAMS.
3. RO FEED WATER BACKWASH TANKS (ONE NO.IN EACH STREAM) ARE PROVIDED WITH PARTITION WALLS IN EACH STREAM.

LEGEND:

(yellow line)	INCOMING RAW SEA WATER
(blue line)	WATER LINE
(red line)	REJECT/ BACKWASH/ DRAIN/ BELT FILTER FILTRATE, SUPERNATANT/ RINSE/ DUMPLINE
(magenta line)	AIR FOR BACKWASH/ MIXING
(green line)	CHEMICAL DOSING
(brown line)	SLUDGE / SCREENINGS
	BLOWER / COMPRESSOR
	PUMP
	INTERFACE POINT
SWRO	SEAWATER REVERSE OSMOSIS
CF	CARTRIDGE FILTER
CIP	CLEAN IN PLACE
HP	HIGH PRESSURE
SMBS	SODIUM META BI SULPHATE

Rev	Date	Description	Drawn	Chkd	Appd
R1	24.06.2020	Conceptual Design Report for CP1	NGM	GM/MM	DD
R0	17.04.2020	Preliminary Draft Conceptual Design Report for CP1	VK	GM	DD

Client: Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

Project management Consultant : SMEC International Pty Ltd , Tata Consulting Engineers Limited (TCE), NJS Engineers India Pvt Ltd (NJSEI) , SMEC India Pvt Ltd.

Project Name: Consultancy for "Design, Preparation of Bid Documents & Evaluation of Bids for the Proposed Construction of 400 MLD Capacity Seawater Reverse Osmosis Desalination Plant at Perur along East Coast Road, South of Chennai, Tamil Nadu and Construction Management & Supervision for the Proposed Desalination Plant and its Product Water Conveyance Pipeline from the Plant and upto Porur and all allied works"

Project Title: PMC for Chennai Perur 400 MLD Desalination Plant and allied works

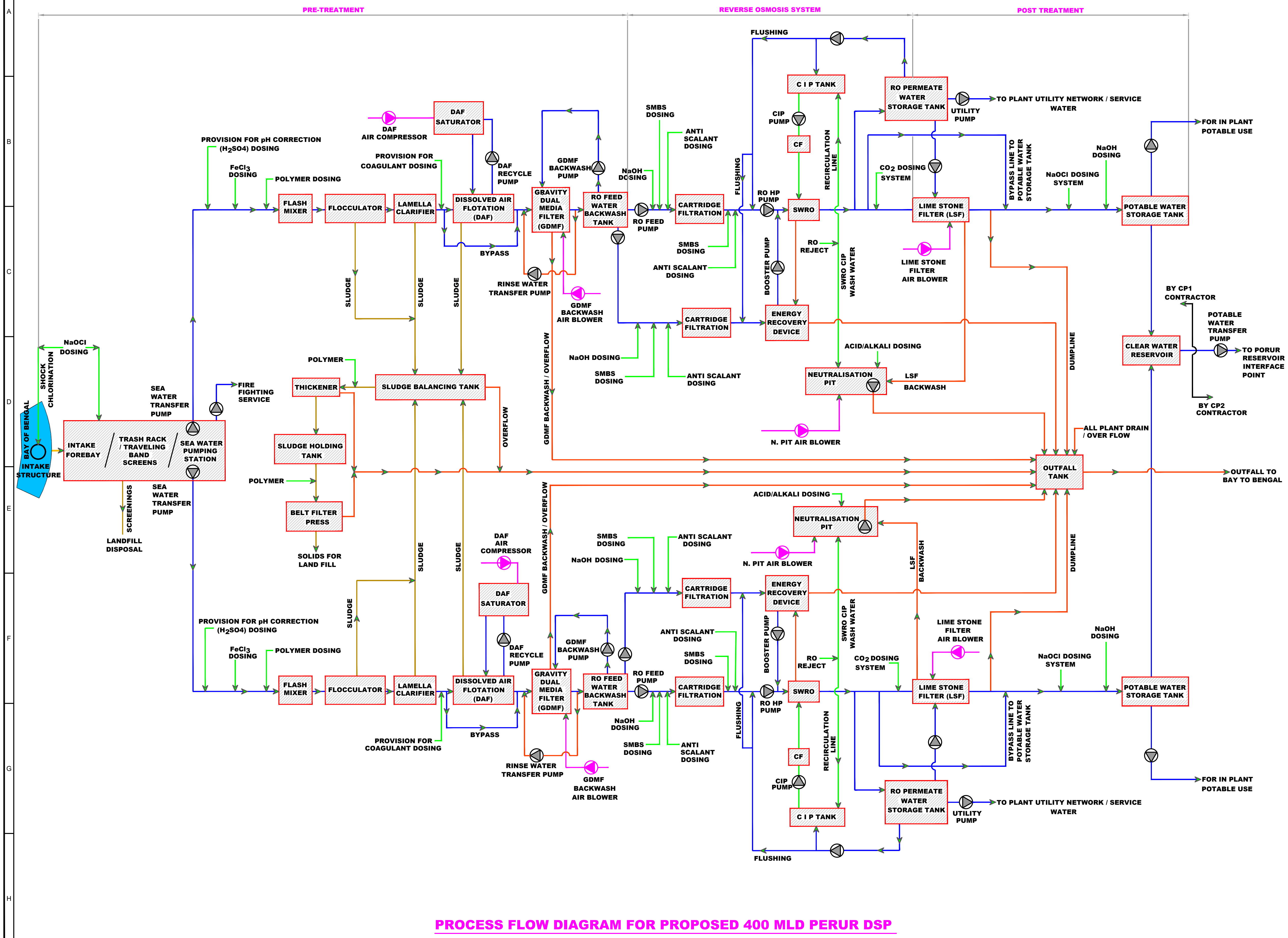
Project Code: Contract Package -1 (CP1)

Status: Conceptual Design Report for CP1

Drawing Title: PROCESS FLOW DIAGRAM FOR PROPOSED 400 MLD PERUR DSP

Drawn : NGM		Checked : GM / MM	
Designed : SMK		Approved : PD	
Date : 11.11.2020		Scale : NTS	
Drawing Number: 7061563/PMC/400MLD/CP1/PFD/001		Sh.No 1 OF 1	Revision: R1

PROCESS FLOW DIAGRAM FOR PROPOSED 400 MLD PERUR DSP



NOTES:

1. TWO (2) STREAMS EACH OF 200 MLD CAPACITY PROPOSED.
2. SEAWATER PUMPING STATION, POTABLE WATER STORAGE TANK, SLUDGE BALANCING TANK, THICKENER, SLUDGE HOLDING TANK, BELT FILTER PRESS BUILDING ARE COMMON UNITS FOR BOTH STREAMS.
3. RO FEED WATER BACKWASH TANKS (ONE NO.IN EACH STREAM) ARE PROVIDED WITH PARTITION WALLS IN EACH STREAM.

LEGEND:

- INCOMING RAW SEA WATER
- WATER LINE
- REJECT/ BACKWASH/ DRAIN/ BELT FILTER FILTRATE,SUPERNATANT/ RINSE/ DUMPLINE
- AIR FOR BACKWASH/ MIXING
- CHEMICAL DOSING
- SLUDGE / SCREENINGS
- BLOWER / COMPRESSOR
- PUMP
- INTERFACE POINT

SWRO	SEAWATER REVERSE OSMOSIS
CF	CARTRIDGE FILTER
CIP	CLEAN IN PLACE
HP	HIGH PRESSURE
SMBS	SODIUM META BI SULPHATE

FOR TENDER PURPOSE ONLY

Rev	Date	Description	Drawn	Chkd	Appd
R1	24.06.2020	Conceptual Design Report for CP1	NGM	GM/MM	DD
R0	17.04.2020	Preliminary Draft Conceptual Design Report for CP1	VK	GM	DD

Client: Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

Project management Consultant : SMEC International Pty Ltd , Tata Consulting Engineers Limited (TCE), NJS Engineers India Pvt Ltd (NJSEI) , SMEC India Pvt Ltd.

Project Name: Consultancy for "Design, Preparation of Bid Documents & Evaluation of Bids for the Proposed Construction of 400 MLD Capacity Seawater Reverse Osmosis Desalination Plant at Perur along East Coast Road, South of Chennai, Tamil Nadu and Construction Management & Supervision for the Proposed Desalination Plant and its Product Water Conveyance Pipeline from the Plant and upto Porur and all allied works"

Project Title: PMC for Chennai Perur 400 MLD Desalination Plant and allied works

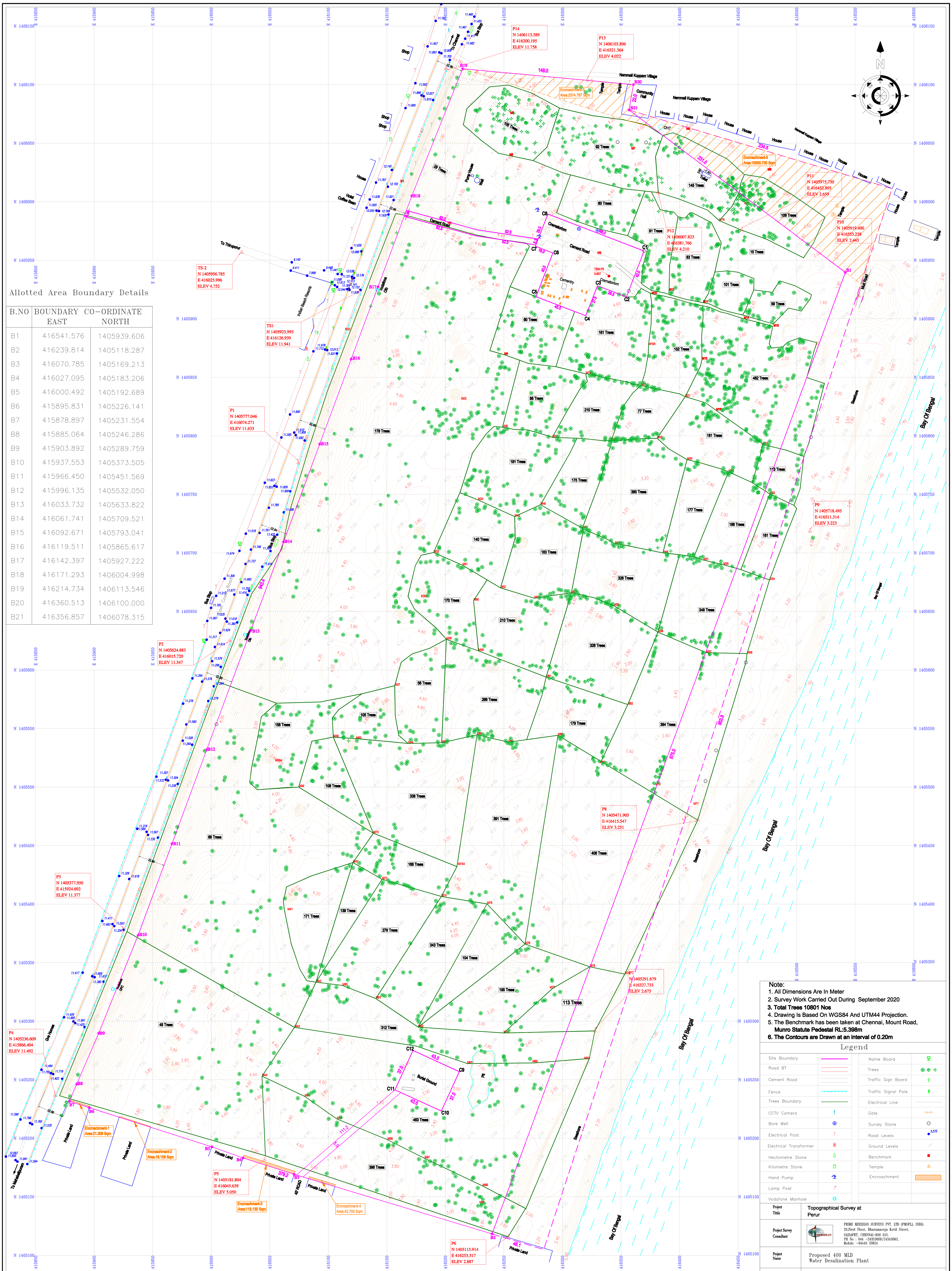
Project Code: Contract Package -1 (CP1)

Status: Conceptual Design Report for CP1

Drawing Title: PROCESS FLOW DIAGRAM FOR PROPOSED 400 MLD PERUR DSP

Drawn :	NGM	Checked :	GM / MM
Designed :	SMK	Approved :	PD
Date :	02.11.2020	Scale :	NTS

Drawing Number:	Sh.No	Revision:
7061563/PMC/400MLD/CP1/PFD/001	1 OF 1	R1



Allotted Area Boundary Details

B.NO	BOUNDARY CO-ORDINATE EAST	NORTH
B1	416541.576	1405939.606
B2	416239.814	1405118.287
B3	416070.785	1405169.213
B4	416027.095	1405183.206
B5	416000.492	1405192.689
B6	415895.831	1405226.141
B7	415878.897	1405231.554
B8	415885.064	1405246.286
B9	415903.892	1405289.759
B10	415937.553	1405373.505
B11	415966.450	1405451.569
B12	415996.135	1405532.050
B13	416033.732	1405633.822
B14	416061.741	1405709.521
B15	416092.671	1405793.041
B16	416119.511	1405865.617
B17	416142.397	1405927.222
B18	416171.293	1406004.998
B19	416214.734	1406113.546
B20	416360.513	1406100.000
B21	416356.857	1406078.315

Note:
1. All Dimensions Are In Meter
2. Survey Work Carried Out During September 2020
3. **Total Trees 10801 Nos**
4. Drawing Is Based On WGS84 And UTM44 Projection.
5. The Benchmark has been taken at Chennai, Mount Road, **Munro Statute Pedestal RL:5.398m**
6. **The Contours are Drawn at an interval of 0.20m**

Legend

Site Boundary		Name Board	
Road BT		Trees	
Cement Road		Traffic Sign Board	
Fence		Traffic Signal Pole	
Trees Boundary		Electrical Line	
CCTV Camera		Gate	
Bore Well		Survey Stone	
Electrical Post		Road Levels	5.575
Electrical Transformer		Ground Levels	2.97
Hectometre Stone		Benchmark	
Kilometre Stone		Temple	
Hand Pump		Encroachment	
Lamp Post			
Vodafone Manhole			

Project Tittle	Topographical Survey at Perur
Project Survey Consultant	PRIME MERIDIAN SURVEYS PVT. LTD (PMSPL), INDIA 29,First Floor, Dharamaraja Kovil Street, SAIDAPET, CHENNAI-600 015. PH No : 044 -24353669/24343663, Mobile: -94440 20824
Project Name	Proposed 400 MLD Water Desalination Plant
Drawing Title	Topo Survey - Spot Levels & Contours

Cad Scale: 1: 1000	Dwg. Scale: 1: 1000 (A0)	Drawing No: PMS/Perur/2020/10/Topo-Contour	Sheet - 01
Signature			
Date	Sep. - 2020	Sep. - 2020	Sep. - 2020
Name	Saravanan	B.Rajesh	G.N.Kumaran
Description	Surveyed	Drawn	Checked

Revisions

Rev.					
Rev.	0				
Rev.	Date	Description	Surveyed	Drawn	Checked

North side Burial Ground Co-Ordinate						South side Burial Ground Co-Ordinate		
P.Id	Easting	Northing	P.Id	Easting	Northing	P.Id	Easting	Northing
C1	416369.681	1405957.891	C5	416277.378	1405918.883	C9	416211.861	1405256.896
C2	416354.627	1405918.681	C6	416291.787	1405956.197	C10	416196.478	1405223.245
C3	416329.887	1405928.179	C7	416276.861	1405961.961	C11	416156.916	1405241.331
C4	416319.855	1405902.574	C8	416287.580	1405989.445	C12	416172.299	1405274.981

Surveyed Area Details:

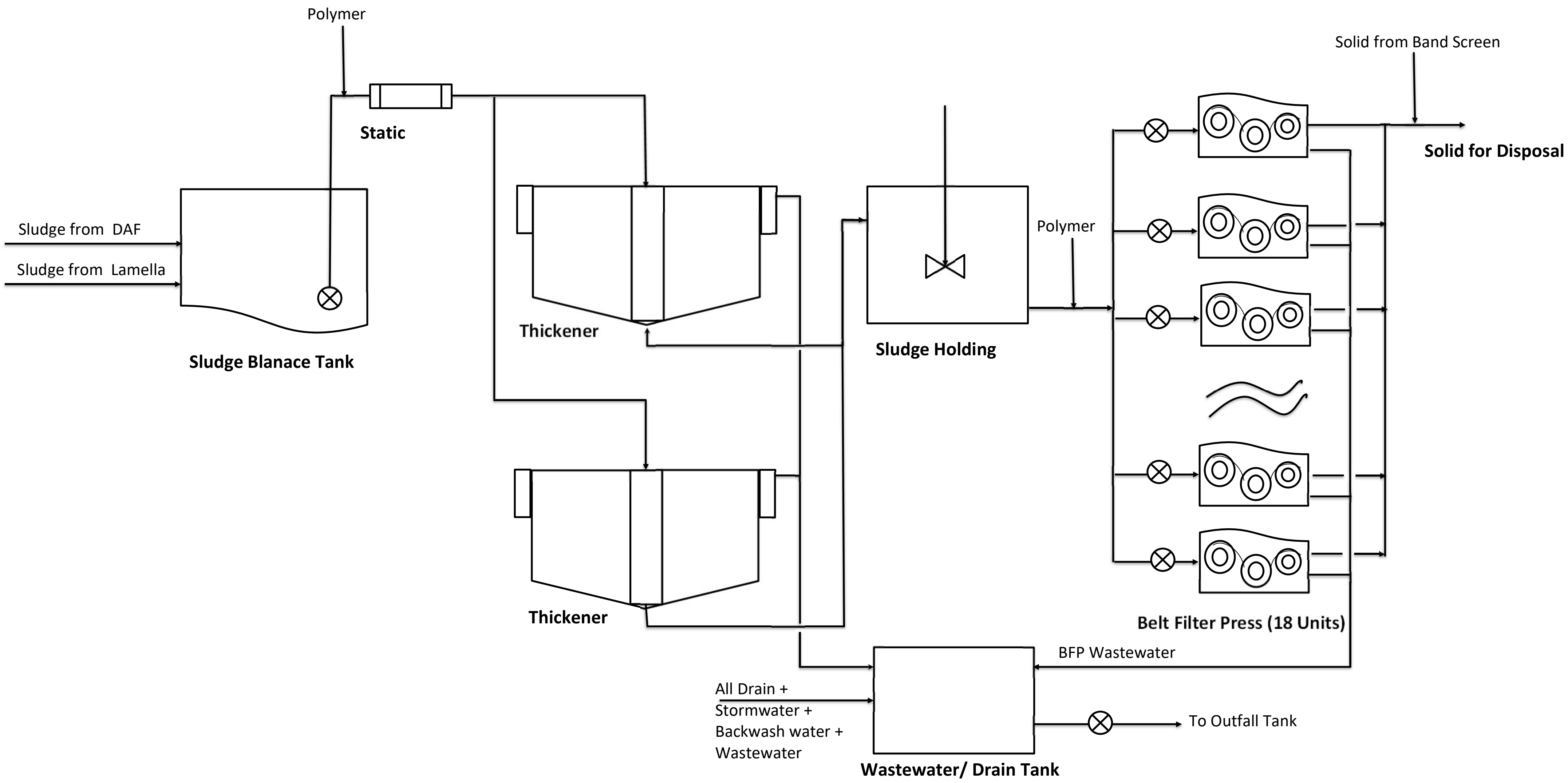
Burial Ground-1
Area:1.32 Acres

Allotted Area
(Exculiding Burial Grounds)
Area:83.696 Acres

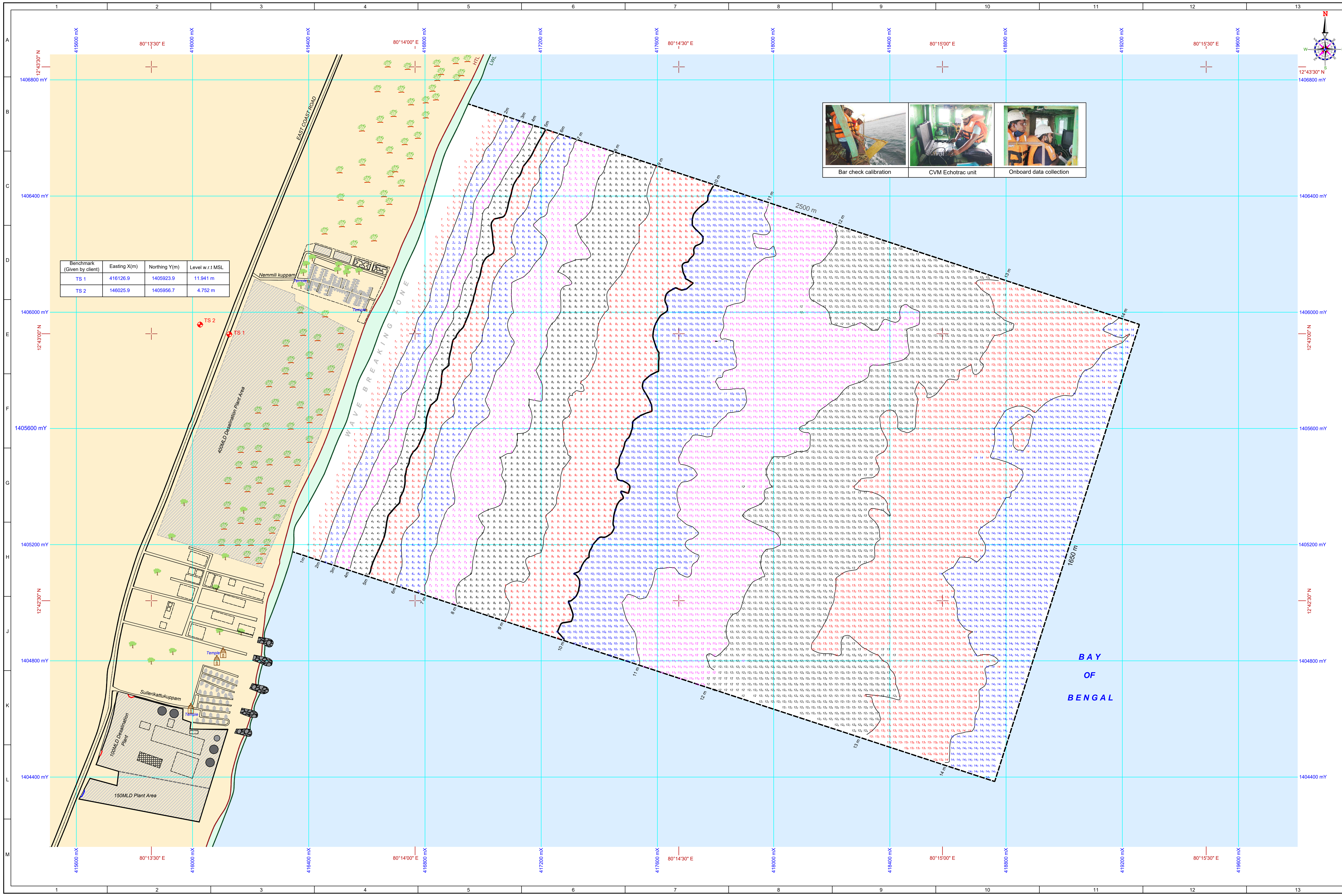
Seashore Land
Area:9.137 Acres

Burial Ground-2
Area:0.53 Acre

SLUDGE TREATMENT SYSTEM

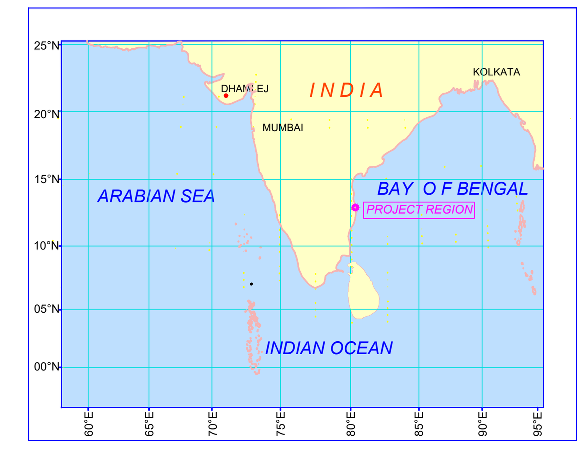


Disclaimer	400 MLD PERUR DSP	Title SLUDGE TREATMENT SYSTEM INDICATIVE FLOW DIAGRAM 400 MLD SWRO PLANT LAYOUT	Consultant:: PMC Clients Number CMWSSB Issued: 0 Drawing Number: 7061563-PMC400MLD-CP1-Sludge Treatment System -001 Rev: 0



Benchmark (Given by client)	Easting X(m)	Northing Y(m)	Level w.r.t MSL
TS 1	416126.9	1405923.9	11.941 m
TS 2	146025.9	1405956.7	4.752 m

LOCATION MAP :



NOTES :

1. WATER DEPTHS ARE REDUCED TO CD USING MEASURED TIDES.
2. HORIZONTAL POSITIONING ACQUIRED USING HEMISPHERE DGPS BEACON RECEIVER.
3. BATHYMETRY ACQUIRED USING ODOM ECHOTRAC CVM DUAL FREQUENCY ECHOSOUNDER.
4. ANNOTATIONS ARE IN METRES AND SUFFIX IN DECIMETRES.
5. CONTOURS DEPTHS ARE IN METRES.
6. SOUNDINGS INTERVALS 20 M X 20M.
7. COASTAL CONFIGURATION BASED ON HEMISPHERE DGPS BEACON RECEIVER.

LEGEND :

GENERAL

GEOGRAPHICAL GRID INTERSECTION

UTM GRID INTERSECTION

BATHYMETRY

13 , 14

GEODETIC DETAILS :

SPHEROID	:	WGS 84
SEMI MAJOR AXIS (A)	:	6378137.00 M
INVERSED FLATTENING (1/F)	:	298.2572
GRID PROJECTION	:	U.T.M. ZONE 44 N
LATITUDE OF ORIGIN	:	0° EQUATOR
LONGITUDE OF ORIGIN (CM)	:	81° EAST
SCALE FACTOR ON CM	:	0.9996
FALSE EASTING	:	500000m E
FALSE NORTHING	:	0m N
UNIT	:	INTERNATIONAL METRE

DEPTHS IN METRES

SCALE :

40 20 0 40 80 120 160 200metres

SCALE 1 : 4000

SURVEY PERIOD : 26.08.2020 TO 28.08.2020

TIDAL INFORMATION :

PLACE	POSITION		HEIGHT ABOVE CHART DATUM				
	LATITUDE	LONGITUDE	MHWS METRE	MHWN METRE	MLWN METRE	MLWS METRE	MSL (m)
CHENNAI	12° 52' N	80°41' E	1.15	0.84	0.43	0.14	0.65

FOR TENDER PURPOSE ONLY

Rev	Date	Description	Drawn	Chkd	Appd
R0					

Client: Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

Project management Consultant : SMEC International Pty Ltd , Tata Consulting Engineers Limited (TCE), NJS Engineers India Pvt Ltd (NJSEI) , SMEC India Pvt Ltd.

Project Name: Consultancy for "Design, Preparation of Bid Documents & Evaluation of Bids for the Proposed Construction of 400 MLD Capacity Seawater Reverse Osmosis Desalination Plant at Perur along East Coast Road, South of Chennai, Tamil Nadu and Construction Management & Supervision for the Proposed Desalination Plant and its Product Water Conveyance Pipeline from the Plant and upto Porur and all allied works"

Project Title: PMC for Chennai Perur 400 MLD Desalination Plant and allied works

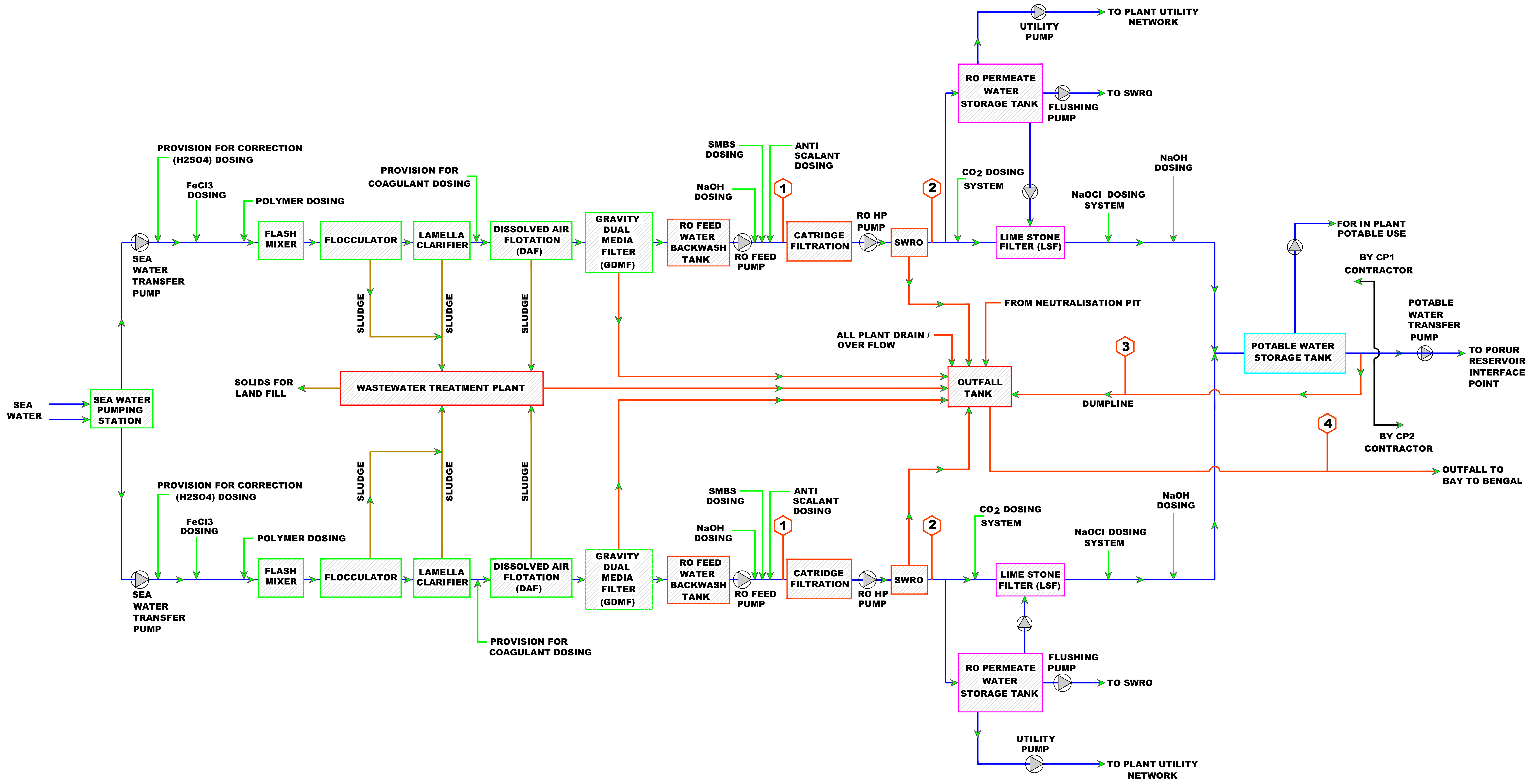
Project Code: Contract Package -1 (CP1)

Status: Conceptual Design Report for CP1

Drawing Title: BATHYMETRY MAP - PERUR

Drawn : J.VINOTHKUMAR / S.VIJAY	Checked : DR. P. CHANDRAMOHAN
Designed : J.VINOTHKUMAR/M.SHARATH /S.VIJAY	Approved : PD
Date : 28.08.2020	Scale :

Drawing Number:	Sh.No	Revision:
7061563/PMC400MLD/CP1/BATM/002	1 OF 1	R0



NOTE:-

(i) CRITICAL CONTROL POINTS

(ii) TWO STREAMS OF EACH 200 MLD.

CRITICAL CONTROL POINTS FLOW DIAGRAM FOR PROPOSED 400 MLD PERUR DSP

NOTES:

1. TWO (2) STREAMS EACH OF 200 MLD CAPACITY PROPOSED

LEGEND:

- INCOMING RAW SEA WATER
- WATER LINE
- REJECT/ BACKWASH/ DRAIN/ BELT FILTER FILTRATE,SUPERNATANT/ RINSE/ DUMPLINE
- AIR FOR BACKWASH/ MIXING
- CHEMICAL DOSING
- SLUDGE / SCREENINGS
- BLOWER / COMPRESSOR
- PUMP
- INTERFACE POINT

SWRO	SEAWATER REVERSE OSMOSIS
CF	CARTRIDGE FILTER
CIP	CLEAN IN PLACE
HP	HIGH PRESSURE
SMBS	SODIUM META BI SULPHATE

FOR TENDER PURPOSE ONLY

Rev	Date	Description	Drawn	Chkd	Appd
R1	21.08.2020	Conceptual Design Report for CP1	NGM	GM/MM	DD
R0	24.06.2020	Conceptual Design Report for CP1	NGM	GM/MM	DD

Client: Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

Project management Consultant : SMEC TATA NJS
SMEC International Pty Ltd , Tata Consulting Engineers Limited (TCE), NJS Engineers India Pvt Ltd (NJSEI) , SMEC India Pvt Ltd.

Project Name: Consultancy for "Design, Preparation of Bid Documents & Evaluation of Bids for the Proposed Construction of 400 MLD Capacity Seawater Reverse Osmosis Desalination Plant at Perur along East Coast Road, South of Chennai, Tamil Nadu and Construction Management & Supervision for the Proposed Desalination Plant and its Product Water Conveyance Pipeline from the Plant and upto Porur and all allied works"

Project Title: PMC for Chennai Perur 400 MLD Desalination Plant and allied works

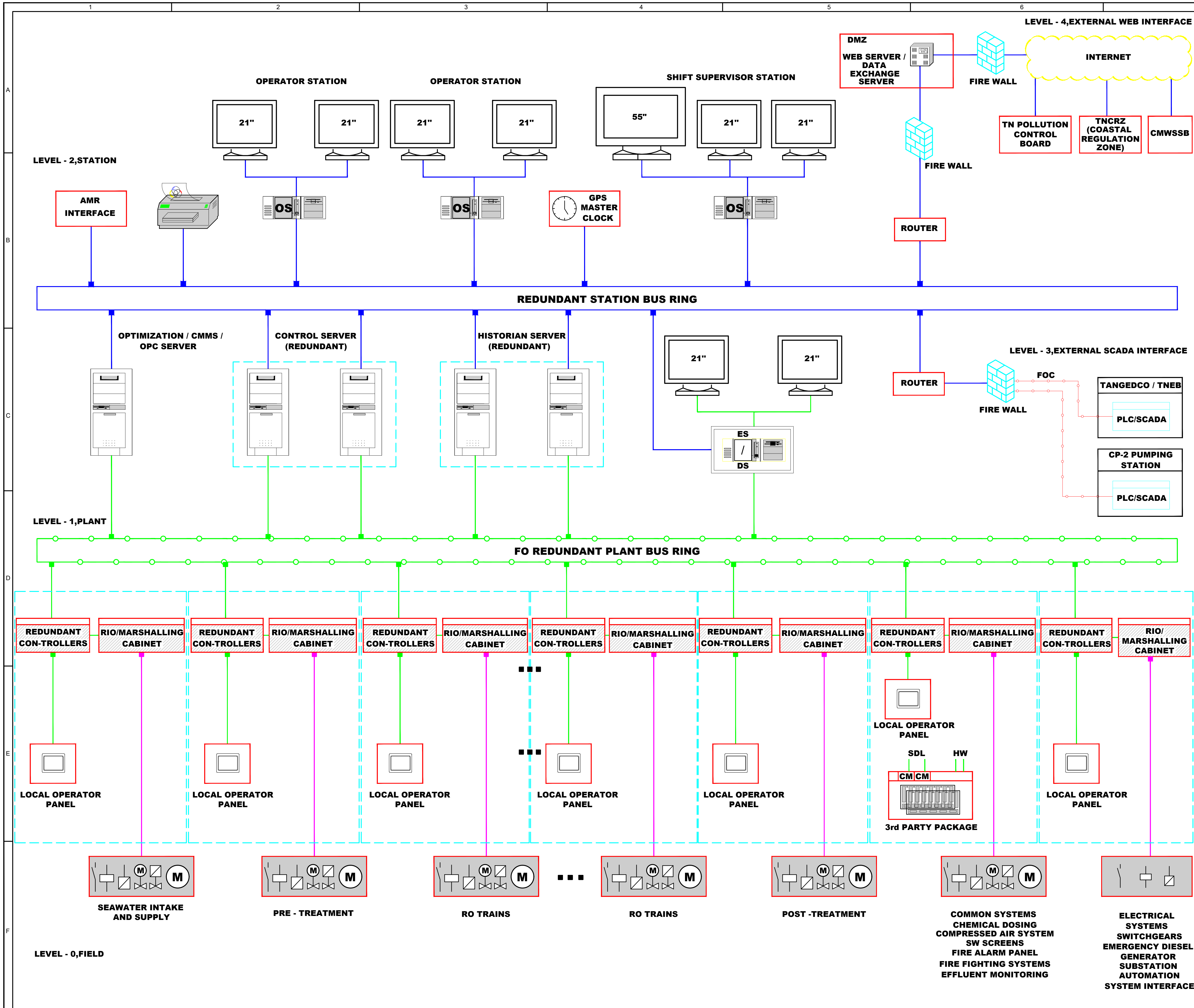
Project Code: Contract Package -1 (CP1)

Status: Conceptual Design Report for CP1

Drawing Title: CRITICAL CONTROL POINTS FLOW DIAGRAM FOR PROPOSED 400 MLD PERUR DSP

Drawn:	NGM	Checked:	GM / MM
Designed:	SMK	Approved:	PD
Date:	21.08.2020	Scale:	NTS

Drawing Number:	Sh.No	Revision:
7061563/PMC400MLD/CP1/CCP/002	1 OF 1	R1



NOTES:

1. THE INDICATED DCS ARCHITECTURE IS TENTATIVE ONLY AND HAS TO BE ADJUSTED TO BIDDERS DESIGN.
2. THE INDICATED NUMBER AND PLANT CONFIGURATION ARE PRELIMINARY.FINAL DESIGN SHALL BE DEFINED BY THA BIDDER.
3. COMMUNICATION WITH TANDEGCO/TNEB AND CP-2 PUMPING STATION SHALL BE BY MODBUS TCP/IP OR OPC.

LEGEND:

1. AMR – AUTOMATIC METER READING SYSTEM (BILLING SYSTEM)
2. CMMS – COMPUTERIZED MAINTENNACE MANAGEMENT SYSTEM
3. DMZ – DEMILITARIZED ZONE
4. DS – DIAGNOSTIC STATION
5. ES – ENGINEERING STATION
6. GPS – GLOBAL POSITIONING SYSTEM
7. HW – HARDWIRED
8. OS – OPERATOR STATION
9. SDL – SERIAL DATA LINK
10. TNCRZ – TAMIL NADU COASTAL REGULATION ZONE
11. TANGEDCO– TAMIL NADU GENERATION AND DISTRIBUTIO
12. TNEB – TAMIL NADU ELECTRICITY BOARD
13. FOC – FIBRE OPTICAL CABLE

FOR TENDER PURPOSE ONLY

Rev	Date	Description	Drawn	Chkd	Appd
R1	10.09.2020	Conceptual Design Report for CP1	NGM	AAL/GM	DD
R0	02.09.2020	Conceptual Design Report for CP1	NGM	AAL/GM	DD

Client: Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

Project management Consultant : SMEC International Pty Ltd , Tata Consulting Engineers Limited (TCE), NJS Engineers India Pvt Ltd (NJSEI) , SMEC India Pvt Ltd.

Project Name: Consultancy for "Design, Preparation of Bid Documents & Evaluation of Bids for the Proposed Construction of 400 MLD Capacity Seawater Reverse Osmosis Desalination Plant at Perur along East Coast Road, South of Chennai, Tamil Nadu and Construction Management & Supervision for the Proposed Desalination Plant and its Product Water Conveyance Pipeline from the Plant and upto Porur and all allied works"

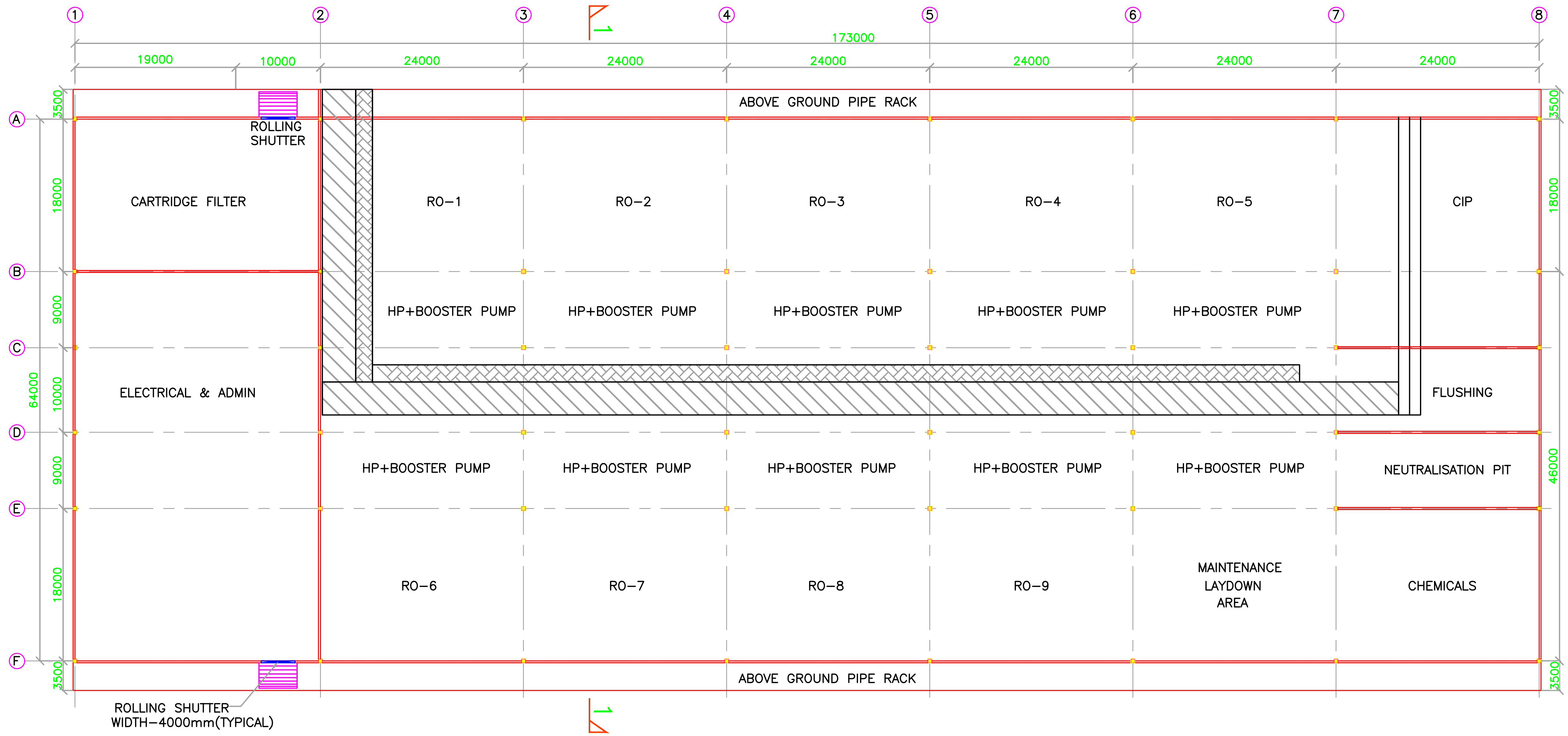
Project Title: PMC for Chennai Perur 400 MLD Desalination Plant and allied works

Project Code: Contract Package -1 (CP1)

Status: MFS DRAWING

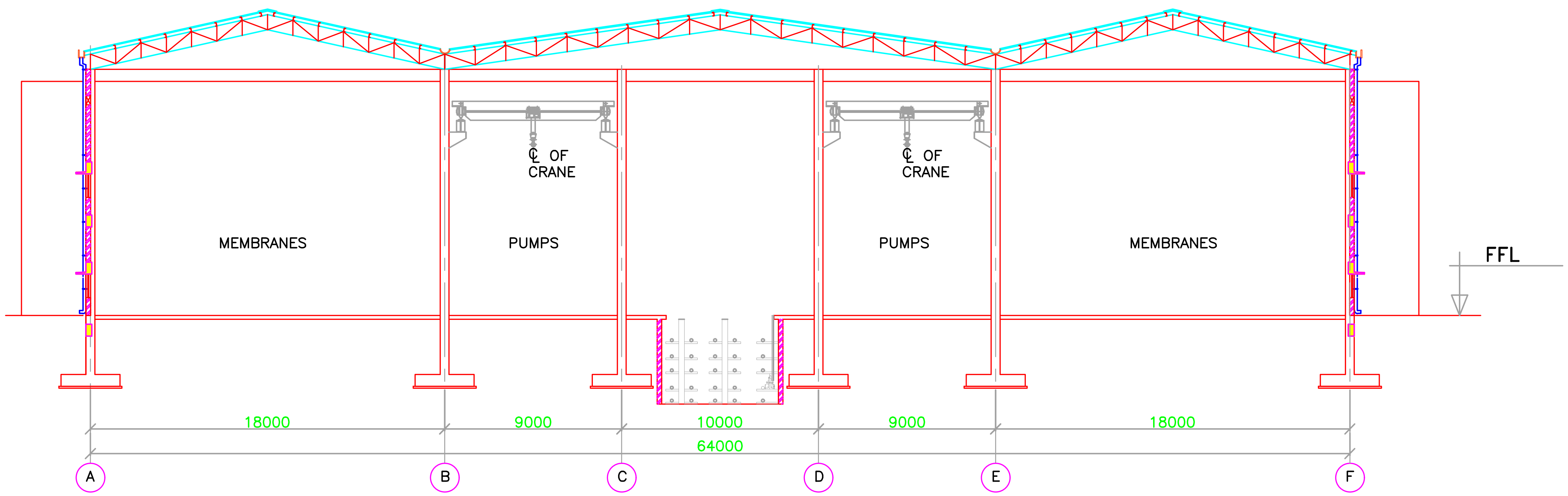
Drawing Title: TENTATIVE DCS ARCHITECTURE & INTERFACES FOR 400 MLD PERUR DSP

Drawn : NGM		Checked : AAL/ GM	
Designed : AAL		Approved : PD	
Date : 10.09.2020		Scale : A3	
Drawing Number: 7061563/PMC400MLD/CP1/DCS/001		Sh.No 1 OF 1	Revision: R1



RO BUILDING PIPE & CABLE TRENCHES

SCALE (1:400)



RO BUILDING CROSS SECTION 1-1

SCALE (1:200)

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETER AND LEVELS IN METER UNLESS SPECIFIED.
2. PEB STEEL STRUCTURE PROPOSED.
3. 2 NOS OF RO BUILDING FOR EACH 200MLD STREAM PROPOSED.
4. EACH 200MLD STREAM HAS 9 TRAINS INCLUDING 1 STAND – BY (25MLD/UNITS).

FOR TENDER PURPOSE ONLY

Rev	Date	Description	Drawn	Chkd	Appd
R0	21.11.2020		NGM	GM/MM	PD

Client: Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

Project management Consultant : SMEC International Pty Ltd , Tata Consulting Engineers Limited (TCE), NJS Engineers India Pvt Ltd (NJSEI) , SMEC India Pvt Ltd.

Project Name: Consultancy for "Design, Preparation of Bid Documents & Evaluation of Bids for the Proposed Construction of 400 MLD Capacity Seawater Reverse Osmosis Desalination Plant at Perur along East Coast Road, South of Chennai, Tamil Nadu and Construction Management & Supervision for the Proposed Desalination Plant and its Product Water Conveyance Pipeline from the Plant and upto Porur and all allied works"

Project Title: PMC for Chennai Perur 400 MLD Desalination Plant and allied works

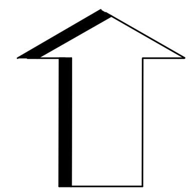
Project Code: Contract Package -1 (CP1)

Status: Conceptual Design Report for CP1

Drawing Title: GENERAL ARRANGEMENT DRAWING FOR RO BUILDING

Drawn : NGM		Checked : GM / MM	
Designed : SMK		Approved : PD	
Date : 21.11.2020		Scale : 1:1	

Drawing Number: 7061563/PMC400MLD/CP1/GAD/002 | Sh.No 1 OF 1 | Revision: R0



NORTH

ALLOTTED AREA BOUNDARY DETAILS

B.NO	BOUNDARY CO-ORDINATE EAST	BOUNDARY CO-ORDINATE NORTH
B1	416541.576	1405939.606
B2	416239.814	1405118.287
B3	416070.785	1405169.213
B7	415878.897	1405231.554
B14	416061.741	1405709.521
B19	416214.734	1406113.546
B20	416360.513	1406100.000
B21	416356.857	1406078.315

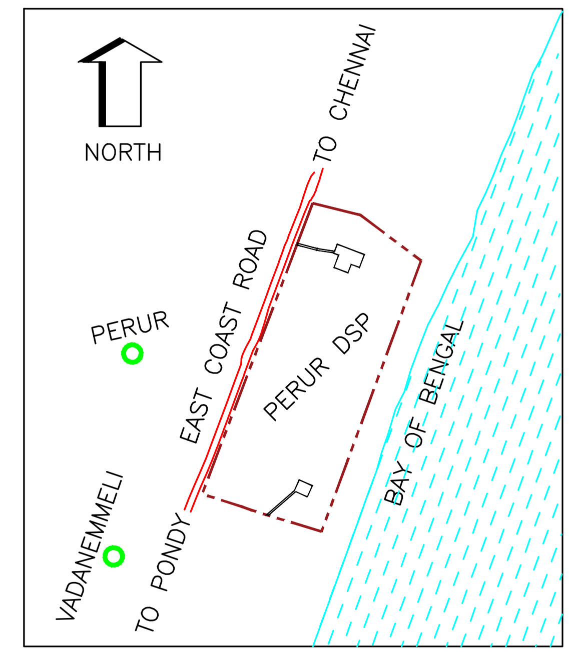
NORTH SIDE BURIAL GROUND CO-ORDINATE			SOUTH SIDE BURIAL GROUND CO-ORDINATE		
P.ID	EASTING	NORTHING	P.ID	EASTING	NORTHING
C1	416369.681	1405957.891	C9	416211.861	1405256.896
C2	416354.627	1405918.681	C10	416196.478	1405223.245
C3	416329.887	1405928.179	C11	416156.916	1405241.331
C4	416319.855	1405902.574	C12	416172.299	1405274.981
C5	416277.378	1405918.883			
C6	416291.787	1405956.197			
C7	416276.861	1405961.961			
C8	416287.580	1405989.445			

400 MLD SEA WATER DESALINATION PLANT AT PERUR COMPONENT LIST (CP–1)

SI NO.	COMPONENT NAME	NO. OF UNITS	MATERIAL OF CONSTRUCTION (MOC)
01	INTAKE PIT	1	RCC EPOXY
02	LAMELLA FILTER	2	RCC EPOXY
03	DAF–DISSOLVED AIR FLOTATION	2	RCC EPOXY
04	GDMF–GRAVITY DUAL MEDIA FILTER	2	RCC EPOXY
05	RO FEED WATER BACKWASH TANK	2	RCC EPOXY
06	RO BUILDING	2	PEB SHED
07	LIME STONE FILTER	2	RCC EPOXY
08	RO PERMEATE WATER TANK	2	RCC EPOXY
09	CO2 STORAGE AREA	2	–
10	POTABLE WATER STORAGE TANK	2	RCC EPOXY
11	CLEAR WATER RESERVOIR	1	RCC EPOXY
13	SLUDGE BALANCING TANK	1	RCC EPOXY
14	THICKENER	2	RCC EPOXY
15	SLUDGE HOLDING TANK	1	RCC EPOXY
16	BELT FILTER PRESS BUILDING	1	RCC
17	OUTFALL TANK	1	RCC EPOXY
18	NEUTRALISATION PIT	1	RCC WITH ACID/ ALKALI PROOF LINING
19	CHEMICAL BUILDING–RO	2	RCC WITH ACID/ ALKALI PROOF LINING
20	CHEMICAL BUILDING PRE–TREATMENT	2	RCC
21	POWER RECEIVING STATION	1	–
21a	CONTROL BUILDING	1	RCC
22	ELECTRICAL BUILDING FOR INTAKE PUMP STATION & PRE–TREATMENT	2	RCC
23	ELECTRICAL BUILDING FOR RO BUILDING	2	RCC
24	WAREHOUSE	1	RCC
25	WORKSHOP	1	RCC
26	PACKAGE STP	1	–
27	FIRE FIGHTING	1	RCC
28	ADMINISTRATION CUM LABORATORY & CONTROL ROOM BUILDING (TWO FLOORS)	1	RCC
29	PARKING AREA	1	PEB SHED
30	SECURITY ROOM	1	RCC
31	CANTEEN BUILDING	1	RCC
32	LAY DOWN AREA	1	–
33	LAY DOWN AREA	1	–

POTABLE WATER PUMPING STATION AT PERUR COMPONENT LIST (CP–2)

SI NO.	COMPONENT NAME	NO. OF UNITS	MATERIAL OF CONSTRUCTION (MOC)
12	POTABLE WATER TRANSFER PUMPING STATION	1	RCC



KEY PLAN

LEGEND :

- SEA WATER
- REJECT PIPE TO SEA
- PROPOSED ROAD
- PROPOSED UNITS
- PROPOSED COMPOUND WALL
- PLOT BOUNDARY
- STROM WATER DRAIN
- CP2 CONTRACTOR'S SCOPE

NOTES :

1. ALL DIMENSIONS ARE IN METRES UNLESS SPECIFIED.
2. TOTAL AREA OF PROPOSED DESALINATION PLANT LAYOUT = 70.24 Acres (2,84,258.7 SQ.M).
3. TOTAL ALLOTTED AREA (EXCLUDING BURIAL GROUNDS) = 83.6 Acres (3,38,673.32 SQ.M).
4. NORTH SIDE BURIAL GROUND AREA (INCLUDING ROAD) = 1.32 Acres (5361.9 SQ.M).
5. SOUTH SIDE BURIAL GROUND AREA (INCLUDING ROAD) = 0.53 Acres (2163.5 SQ.M).
6. THE BENCHMARK HAS BEEN TAKEN AT CHENNAI,MOUNT ROAD, MUNRO STATUTE PEDESTAL RL:5.398M

TEMPORARY BENCHMARK:

NO	CO–ORDINATE EAST	CO–ORDINATE NORTH
TS1	416126.939	1405923.993
TS2	416025.996	1405956.785

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Rev	Date	Description	Drawn	Chkd	Appd
R0	13.10.2020		NGM	GM	DD

Client: Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB)

Project management Consultant : SMEC International Pty Ltd , Tata Consulting Engineers Limited (TCE), NJS Engineers India Pvt Ltd (NJSEI) , SMEC India Pvt Ltd.

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Project Title: PMC for Chennai Perur 400 MLD Desalination Plant and allied works

Project Code: Contract Package -1 (CP1)

Status: Conceptual Design Report for CP1

Drawing Title:

PLANT LAYOUT FOR 400 MLD PERUR DSP

Drawn :	NGM	Checked :	GM
Designed :	SMK	Approved :	PD
Date :	13.10.2020	Scale :	A1

Drawing Number:	Sh.No	Revision:
7061563/PMC400MLD/CP1/LAY/002	1 OF 1	R0