SPECIFICATION

ELECTRICAL SERVICES

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EGRS - GENERAL REQUIREMENTS

1.0 GENERAL REQUIREMENTS

1.1 Codes, Standards and Regulations

Unless otherwise specified, the work performed under this Contract shall comply in all respects with the current requirements of:

(a) Occupational Safety and Health Act 1994.

(b) Factory and Machinery Act 1967 and Factory and Machinery (Safety, Health and Welfare) Regulations 1970.

(c) The Regulations of Jabatan Keselamatan dan Kesihatan Pekerjaan.

(d) The Uniform Building By-Law 1984.

(e) Local Council, where the works are to be carried out.

(f) Rules, regulations, and requirements of Jabatan Bomba dan Penyelamat Malaysia.

(g) Building Operations and Engineering Construction (Safety) Regulation 1986.

(h) Electricity Supply Act 1990.

(i) Electricity Regulation 1994

(j) IEE Wiring Regulations BS 7671: 2018

(k) Tenaga Nasional Berhad.

(l) Rules and regulations of Suruhanjaya Tenaga.

(m) Telekom Malaysia Berhad

(n) Malaysian Communications and Multimedia Commission Act 1998 (Act 589)

(o) Communications and Multimedia Act (Act 588)

(p) Jabatan Alam Sekitar

(q) Air Selangor

(r) Suruhanjaya Perkhidmatan Air Negara (SPAN)

(s) The relevant Malaysian Standards, British Standards, Codes of Practice where applicable

1.2 Scope of Works

The scope of works shall be as detailed in the Specification, Drawings and Bill of Quantities or Schedule of Prices including

(a) Specified Mechanical and Electrical Works

(b) Submittals

(c) Implementation of QA procedures

(d) Testing and Commissioning

(e) Operation and Maintenance Training Program

(f) Warranty of Equipment and Systems

(g) Service and Maintenance during Defects Liability Period

1.3 General Requirement on Plant and Installation

In complying with the requirements of this Specification, the design and workmanship shall conform to the best current engineering practice. Each of the several parts of the Plant shall be of the manufacturer's standard design while meeting the requirements of this Specification. All similar parts of the Works shall be interchangeable.

The essence of design shall be simplicity and reliability to give long continuous and efficient service with low maintenance cost. Particular attention shall be paid to internal and external access in order to facilitate inspection, cleaning and maintenance.

The design, dimensions and materials of all parts of the Works shall be such that they will not suffer damage as a result of stresses under the most severe service conditions.

Fully detailed specification of the parts of the Plant shall be submitted with the factory working drawings and erection drawings describing particularly the materials to be used.

The materials used in the construction of the Plant shall be of the highest quality and selected particularly to meet the duties required of them. Materials which may be liable to attack by termites or other insects shall not be used. Detachable parts shall be constructed to avoid adhesion due to any cause.

The Plant shall operate without undue vibration and with the least possible amount of noise such that nuisance is not created.

The Plant shall be designed to minimise the risk of fire and any damage which may be caused in the event of fire.

The Plant shall be designed to prevent ingress of all vermin, accidental contact with live parts and to minimise the ingress of dust and dirt.

Detailed planning and co-ordination by Contractor will be necessary to achieve a fully co-ordinated and efficient installation particularly with regard to sequence of erection. Precise positioning and handling of all items forming the total system having due regard to proper access for ease of maintenance and replacement shall be undertaken.

1.4 Submittals

The following submittals shall be forwarded to the Engineer for approval before the scheduled dates indicated.

	Submittals	Submission Date	Nos. of Copy
1.	Draft Quality Assurance Plan	2 Weeks After Award	2

2.	Final Quality Assurance Plan	4 Weeks After Award	4
3.	Builder's Work and Drawings	4 Weeks After Award	4
4.	Method Statements	4 Weeks After Award and Progressively	4
5.	Technical Data and Samples	4 Weeks After Award and Progressively	2
6.	Schedule of Shop Drawings Submission	3 Weeks After Award and Revision Progressively	4
7.	Shop Drawings	12 Weeks Before Commencement of each Section of Work.	6
8.	Site Inspection and Test Procedures and Forms	12 Weeks Before Commencement of each Section of Work.	4
9.	Factory Test Report for Major Equipment	Before Shipment of Equipment	4
10.	Final Draft As Built Drawings	4 Weeks Before Testing and Commissioning	3
11.	Final As Built Drawings	2 Weeks After Completion of Testing and Commissioning	As per Section 1.5.10
12.	Testing and Commissioning Procedures and Forms	12 Weeks Before Testing and Commissioning	4
13.	Testing and Commissioning Report	2 Weeks After Completion of Testing and Commissioning	4
14.	Final Draft of O&M Manual	4 Weeks Before Testing and Commissioning	3
15.	Final of O&M Manual	4 Weeks After Testing and Commissioning	5

1.5 Requirements and Contents of Submittals

1.5.1 General

The submittals shall contain no less than the information listed below. Additional information may be included if deemed necessary.

1.5.2 Quality Assurance Plan

The complete submission shall include:

- Outline of Contractor's Quality Management System
- Project Organization Chart
- Health and Safety Plan (if not covered by Building Contractor)
- Inspection and Test Plan highlighting list of tests and inspection to be carried out, frequency of test and inspection, reference standard.
- Procedures for Document Control
- Procedures for Control of Material Delivery to Site
- Procedures for Control of Defective Works and Rejected Works
- List of Method Statements
- List of Site Inspection & Test Procedures and Forms
- List of Testing and Commissioning Procedures and Forms

1.5.3 Builder's Work and Drawing

Within four weeks of acceptance of Tender, the Contractor shall submit three copies of fully detailed and dimensioned drawings showing any necessary Builder's Works required in connection with the equipment, together with full technical information to enable the associated electrical installation work to be checked or re-designed. Failure to provide the correct information will result in the corrective work being carried out at the expense of the Contractor.

1.5.4 Method Statements

Each method statement shall include:

- Scope of works
- Reference to specification, code of practice and recognized Malaysian and international standard.
- Step by step procedure in carrying out the works and illustrate with sketches where applicable.
- List of site inspection and test to be carried out and make reference to site inspection and test procedures.
- Precautions in executing the works.
- List of tool and special equipment requirement in carrying out the work.

1.5.5 Technical Data and Samples

Each submission of technical data and sample shall include

- Tabulation of specification and technical data of equipment or material proposed with respect to Contract Specifications.
- Tabulation of motor rating and electrical data.
- Legible English version of technical catalogs, literatures and performance curves to substantiate the technical data of equipment proposed.
- Letter of approval from Authorities having jurisdiction over the works or equipment (where applicable).
- Test report from independent laboratories (where applicable).
- Samples fastened or clamped onto a sample board.

1.5.6 Schedule of Shop Drawings Submission

The schedule of shop drawings submission for each service shall contain:-

- List of shop drawings to be submitted
- Planned submission date and actual submission date of each drawing
- Records of amendments and revisions to shop drawings
- Approval status of each drawing and date of approval.

The schedule of shop drawings submission shall be updated periodically.

1.5.7 Shop Drawings

The shop drawings shall include the following information:-

- Plan view showing the routing and level of services
- Sections showing the level of services, access to services, clearance for installation and maintenance, and clearance for other services
- Coordinated plans and sections indicating all services including clearance for installation and maintenance.
- Tabulation of brand name, model no. and capacity of major equipment and components.
- Schematic drawings showing the Mechanical and Electrical Systems and control systems.
- Details of plinths, mounting brackets, trust blocks, anchor bolts and supports.
- Unique drawing non- repeated number and revision number
- Approved standard title block.
- Manufacturer's shop drawing for MSB, SSB, DB and all relevant electrical boards and parts.

The shop drawing submission shall be in both printed form and electronic media (BIM Model of LOD 400 in REVIT 2020 and also in PDF Format).

1.5.8 Site Inspection and Test Procedures and Forms

The site inspection and test procedures and forms shall contain the following information:-

- Reference to specification, code of practice and Malaysian Standard or internationally recognized standard.
- Step by step procedure in carrying out the inspections and tests.
- Criteria for passing the site inspections and tests.
- List of calibrated measuring instruments and gauges to be used.
- Site Inspection and Test Forms with the following information.
  - Checklist of item of work to be inspected
  - Column to enter test results
  - Reference to shop drawings and/or construction drawings
  - Space for signature by supervisor who conducts the inspection or test, Engineer's representative who endorses the inspection and test results and where applicable owner's representative who witnesses the inspection and test.
  - Distribution list
  - Date of inspection and test
  - Unique inspection and test reference number.

1.5.9 Factory Test Report for Major Equipment

Factory test report for the designated equipment shall contain the following information:-

- Reference to specification and internationally recognised standards.
- Extract of relevant section of test standard
- Procedure in carrying out tests
- List of calibrated measuring instruments and gauges
- Calibration report for measuring instruments and gauges from recognised institute or laboratory.
- A plot of measured performance data against manufacturer's published performance curves.
- Signature of manufacturer's engineer who conducted the test.
- Signature of Engineer's representative and the Owner's representative who witnessed the tests (if applicable).
- Sketches, drawings or photographs showing the set-up of measuring instrument, gauges and equipment under test.

1.5.10 As Built Drawings

The requirement for as built drawings shall be:-

- Same requirement as for shop drawings and to incorporate all amendments made during construction complete with contractor's company stamp & signature.
- Softcopy in five sets of DVDs in BIM model (LOD 500 in REVIT 2020), and also in PDF Format.
- Five sets of paper prints to be bound in O&M Manuals.

1.5.11 Testing and Commissioning Procedures and Forms

Testing and Commissioning procedures shall include:-

- Reference to specification, code of practice, Malaysian Standard or internationally recognised standard.
- Sketches and drawings indicating the set-up of measuring instrument and gauges.
- Step by step procedure in carrying out the tests.
- List of calibrated measuring instruments and gauges.
- List of tests to be carried out for each equipment or sub-system.
- Acceptable tolerance for field measured data.
- Criteria for passing tests.

1.5.12 Testing and Commissioning Forms with the following information.

- Specification performance data for equipment and sub-system
- Checklist for functional test
- Column for entering field measured data and operating parameter.
- Column for remarks and details of deficiency.
- Space for signature by supervisor who conducted the tests, Engineer's representative who endorsed the test results and where applicable the owner's representative who witnessed the tests.
- Distribution list
- Date of test
- Non repeated test reference number.

1.5.13 Testing and Commissioning Reports

The testing and commissioning reports shall include:-

- Directory identifying the organization of the testing and commissioning reports in systematic and logical order.
- Approved testing and commissioning procedures.
- Calibration reports of measuring instruments and gauges from recognized institution and laboratory.
- Sketches, schematic, drawings and photograph showing the set-up of measuring instruments and gauges.

- Endorsed copy of testing and commissioning forms.
- Explanation of variance of final measured data and designed value.

1.5.14 Operations And Maintenance Manuals

The complete Operation and Maintenance (O&M) Manual shall comprise the following documents:-

- Directory identifying each section of the document.
- Emergency and agency notification procedures.
- Operating Manual containing information on:-
  - Building function.
  - Building description.
  - Operating standards and logs
  - System description
  - Operating routine and procedures
  - Special procedure (if any)
  - Basic trouble shooting procedure.
- Maintenance Manual Containing
  - Equipment data sheet and list of suppliers
  - Information on warranty
  - Installation, operation and maintenance instructions
  - List of spare parts
  - Preventive maintenance actions
- Test reports documenting set points and observed performance during start up and commissioning.
- As-built drawings in printed form and electronic media.
- Manufacturers' technical literature comprising performance curves, technical catalogs and technical information.

1.6 Tools, Appliances and Test Equipment

Each tool, appliance and test equipment required to be supplied shall be marked clearly indicating its size and intended purpose and shall not be used in the erection of the Plant. Factory certificates shall be provided.

Contractor shall demonstrate to Engineer, the use of the tools, appliances and test equipment and trouble shooting and maintenance procedures before the tools and appliances are taken over by the Employer. All tools and appliances shall be placed in appropriately labelled storage boxes and shall be supplied complete with accessories including probes and power leads.

1.7 Operations And Maintenance Training Program

1.7.1 Objective

The objective of the O&M training program is to provide the Employer's staff with the knowledge to operate and maintain vertical transportation system in accordance with design intent, manufacturers' recommendations, and procedures contained in the O&M Manual. Lecture notes shall be supplied for the training. The training shall be conducted by persons with specific expertise in each aspect of the lift system. As part of the training programme, the Contractor shall supply ten (10) sets of the Training Manual necessary to implement the programme.

1.7.2 Scope of Training

The training program shall furnish a thorough understanding of all equipment, components, systems, and their operation. The training shall include the following topics.

(a) Use of O&M Manual with an emphasis on

- Design intent
- Description, capabilities, and limitation of the systems
- Operation procedures for all modes of operation
- Procedure for dealing with abnormal conditions and emergency situation
- Use of operation manuals
- Use of maintenance manuals

(b) Recommended procedures for collecting and interpreting specific performance data.
(c) Specialized manufacturers' training programs.

1.8 Abbreviations

The following abbreviations shall have the respective meanings assigned to them:

'	-	minute
%	-	percent
RM	-	Ringgit Malaysia
amp	-	amperes
AC	-	alternating current
AISI	-	American Iron and Steel Institute
AMF	-	Automatic Mains Failure
ASHRAE	-	American Society of Heating, Refrigeration and Air-conditioning Engineers
AVR	-	Automatic Voltage Regulator
ACB	-	air circuit breaker
Bomba	-	Jabatan Bomba dan Penyelamat Malaysia

BS	-	British Standard
cd	-	candela
CIE	-	International Commission of Illumination
CP	-	Codes of Practice
dB	-	decibel
DB	-	distribution board
DC	-	direct current
DF	-	distribution frame (Telekom)
DOE	-	Department of Environment
ELCB	-	earth leakage circuit breaker
fluo	-	fluorescent
g	-	gram
hr	-	hour
HT	-	High Tension (11 kV)
Hz	-	hertz
HPSV	-	high pressure sodium vapour
HRC	-	High rupturing capacity
HRCQ	-	heat resistant cold quenched
ICAO	-	International Civil Aviation Organisation
IDMT	-	Inverse Definite Minimum Time
IEC	-	International Electrochemical Commission
IEE	-	Institute of Electrical Engineers, UK
JBEG	-	Jabatan Bekalan Elektrik dan Gas
JKKP	-	Jabatan Keselamatan dan Kesihatan Pekerjaan
kA	-	kiloampere
kg	-	kilogram
kHz	-	kilohertz
km	-	kilometer
kPa	-	kilopascal
kW	-	kilowatt
kV	-	kilovolt
kVA	-	kilovolt ampere
LV	-	low voltage
TMB	-	Telekom Malaysia Berhad
TNB	-	Tenaga Nasional Berhad
l	-	litre

m	-	meter
m2	-	square meter
m3	-	cubic meter
mA	-	milliampere
mm	-	millimeter
mm2	-	square millimeter
M&E	-	Mechanical and Electrical
MCB	-	Miniature circuit breaker
MCCB	-	moulded case circuit breaker
MSB	-	main switchboard
MCSC	-	moving coil with shunt circuit
MHz	-	megahertz
MICC	-	mineral insulated copper cladded
No	-	number
NFPA	-	National Fire Protection Association
o	-	degree
oC	-	degree Celsius
PA	-	Public Address Systems
PCB	-	printed circuit board
PILCSWA	-	paper insulated lead covered steel wire armour
PVC	-	polyvinylchloride
Qty	-	quantity
r.m.s	-	root mean square
RPM	-	revolutions per minute
SDF	-	Subscriber Distribution Frame
SF6	-	sulphur hexafluoride gas
SWA	-	steel wire armoured
SWG	-	Standard Wire Gauge
SSB	-	sub-switchboards
SSO	-	switch socket outlet
TEFC	-	totally enclosed fan cooled
V	-	volt
VCB	-	vacuum circuit breaker
W	-	watt
XLPE	-	Cross link polyethy

END OF SECTION

ETRS - GENERAL TECHNICAL REQUIREMENTS

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ETRS - GENERAL TECHNICAL REQUIREMENTS

1.0 GENERAL

1.1 Code and Standards

This section shall be designed and constructed in accordance with the latest revision of the following standards and the appropriate BS/IEC;

Standards	Document Title
BS EN 60085:2008	Electrical insulation. Thermal evaluation and designation
BS EN 60051-1:1999	Direct acting indicating analogue electrical measuring instruments and their accessories. Definitions and general requirements common to all parts
BS EN 62053-11:2003	Electricity metering equipment (a.c.). Particular requirements. Electromechanical meters for active energy (classes 0,5, 1 and 2)
BS 6231	Flame propagation
BS 88	Fuses
BS EN 60947-4-1	Low-voltage switchgear and control gear. Contactors and motor-starters. Electromechanical contactors and motor-starters
BS EN 60947-2	Low-voltage switchgear and control gear. Circuit-breakers
BS EN 60898-1:2003+A13:2012	Electrical accessories ± Circuit breakers for overcurrent protection for household and similar installations. Circuit-breakers for a.c. operation
BS EN 61869-2:2012	Instrument transformers. Additional requirements for current transformers
BS EN 61869-3:2011	Instrument transformers. Additional requirements for inductive voltage transformers
IEC 255-4	Electrical Relays - Single Input Energizing Quantity Measuring Relays with Dependent Specified Time
BS EN 61008-1:2012+A11:2015	Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs). General rules

BS EN 61008-2-1	Specification for residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs). Applicability of the general rules to RCCBs functionally independent of line voltage
BS EN 61009-1:2012+A12:2016	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs). General rules
BS EN 61009-2-1	Specification for residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs). Applicability of the general rules to RCBOs functionally independent of line voltage
IEC 62521-11:2003	Electricity metering equipment (AC) - General requirements, tests and test conditions - Part 11: Metering equipment

1.2 Packing

Each Plant shall be packed properly and protected for transport from the place of manufacture to the Site. The packing and protection used shall remain good for a period of at least 6 months after delivery to Site.

Ends of tubes and other similar open ends shall be protected from external damage and ingress of dirt and moisture during transit and before erection. Open ends of flanged pipes shall be protected by adhesive tape or jointing and covered with a wooden blank flange secured by service bolts.

Precautions shall be taken to protect shafts and journals resting on supports. At support points, wrappings impregnated with suitable anti-rust compounds or vapour inhibitors shall be used to resist chafing and indentation due to movement.

For ball or roller bearings installed in any of the Plant, Sub-Contractor shall before such plant is transported, submit to The-Contractor or his representative for approval the precautions to be taken to prevent indenting the bearing faces.

Contents of packings shall be bolted securely or fastened in position with struts or cross battens. Where wood chocks are used, they shall be fastened firmly in place. Where parts are required to be bolted to the sides of the packings, large washers shall be used to distribute the pressure. The struts and battens shall be strengthened by means of a pad. Cases shall be up-ended after packing to demonstrate that there is no movement of the contents.

Waterproof paper and felt linings shall overlap at seams of at least 12mm width and the seams shall be secured together in an approved manner. Such paper and felt wrappings shall have screened openings for ventilation purposes.

Where practicable, all indoor items such as electric motors, switches and control gear, instruments and panels, machine components and the like shall be "cocooned" or covered in polyethylene sheeting, sealed at the joints and the enclosure provided with an approved desiccator.

All packings shall be clearly marked on the external surface to show the total weight, the points where the weight is bearing, and the correct position where slings are to bear. An identification mark relating them to the appropriate shipping documents and packing list shall also be marked. All marks shall be of a waterproof material. Otherwise they shall be protected by shellac or varnish to prevent obliteration.

Hoop bindings of packings shall be sealed where ends meet and shall be painted if the material is susceptible to corrosion.

Each packing shall have a packing list in a waterproof envelope and copies in triplicate shall be forwarded to The-Contractor or his representative at least 3 weeks before arrival of the respective packing on Site. Before transportation to Site, each packing shall be treated with an approved fungicide. Sleeving and fabrics treated with linseed oil or linseed oil varnishes shall not be used.

The-Contractor or his representative shall have the right to inspect and approve the packings before the packings are transported but such inspection and approval shall not relieve Sub-Contractor of his obligations and liabilities under the Contract.

1.3 Erection Marks on Multipart Assemblies

All plant comprising multipart assemblies such as steel frameworks and pipe installation shall be marked with distinguishing numbers and/or letters corresponding to those shown on the approved The-Contractor or his representative's Drawings or material lists. These erection marks, if impressed before painting or galvanizing, shall be clearly legible after painting or galvanizing.

1.4 Cleaning, Protection of Surfaces and Painting

All bright metal parts shall be covered before shipment with an approved protective compound and protected adequately during transportation to Site. After erection, these parts shall be cleaned with a suitable solvent and the metal parts polished bright.

All metal work to be painted, except where the finish painting or polishing is to be completed in the factory, shall be well brushed down and given one coat of red lead paint before transportation to Site.

All parts which will be buried in concrete, shall be cleaned and protected by a cement wash or other approved method before transportation to Site. Before being built into the concrete, these parts shall be thoroughly desiccated and cleaned of all rust and adhering matter.

Where two finishing coats of paint are specified, the first coat shall be of a different shade from the second. Where aluminium paint is specified, the undercoat shall be slightly coloured by the addition of washing blue.

Interiors of tanks and similar containers shall be thoroughly cleaned by shot blasting or wire brushing before painting. Fuel tanks shall be corrosion free and left untreated internally. Tanks to store other oils shall be painted with a suitable oil resisting varnish or enamel.

The interior of outdoor control cubicles, cabinets and the like where condensation is liable to occur shall be coated with an approved anti condensation compound.

1.5 Lubrication

The Works shall include the supply of the oil required for flushing each lubrication system and the first filling of approved lubricants.

A schedule of the oils and other lubricants recommended by the manufacturer for all components of the Plant shall be submitted to The-Contractor or his representative for approval. The types of lubricants shall be kept to a minimum and must be readily obtainable in Malaysia. A copy each of this schedule shall be included in each of the draft and final Operation and Maintenance Manuals. For grease lubricated roller bearings of electric motors, lithium grease shall be used in preference over other grease if it is one of the grease types recommended by the manufacturer of the bearing.

Sub-Contractor shall supply at least one grease gun for each category of nipple provided. Where more than one type of grease is required, a grease gun for each grease type shall be supplied and the gun permanently labeled accordingly.

1.6 Rating Plates and Name Plates

Each of the Plant shall have a rating plate permanently attached to it in a conspicuous position. The rating plate shall be of a durable and corrosion resisting material and shall be engraved with identifying name, type or serial number together with details of the loading conditions under which the plant has been designed to operate and such diagram as may be required by The-Contractor or his representative.

1.7 Locks

Locks shall be of the Yale brand or approved equivalent. Three keys shall be supplied for each lock and all locks shall not be interchangeable. Where a set of locks is provided under any particular section of a plant, a group master key shall be supplied as well.

All locks shall be of brass. Where fitted to doors, locks shall be chromium plated.

Locks shall be designed, constructed and located on the Plant so that they remain serviceable in the climatic conditions specified without operation or maintenance for two years.

Where a group of locks are supplied with any of the Plant, a rack or cabinet of approved design shall be supplied to house the padlocks and/or keys not in use. The locks and keys shall be engraved with a suitable identifying code and this identifying code shall be displayed on the racks or cabinets on engraved labels attached thereto.

1.8 Protection of Materials against Weather

In choosing materials and their finishes, due regard shall be given to the humid tropical environment under which the Plant will work.

a) Metals

Stainless steel shall be used to the extent possible. Iron and mild steel shall be painted or galvanized as appropriate in accordance with Sub-Clauses 1.4 of this Specification. Indoor parts may have chromium or copper-nickel plating or other approved protective finish. Small iron and steel parts (other than steel not susceptible to corrosion), the cores of electromagnets and the metal parts of relays and mechanisms shall be treated in an approved manner to prevent corrosion. Cores and the like which are built up of laminations or cannot for any other reason be treated against corrosion, shall have all exposed parts thoroughly cleaned and heavily enameled, lacquered or protected.

Where different metals are in contact, they shall be selected so that the potential difference between them in the electro-chemical series is not greater than 0.5V. Otherwise, the contact surfaces of one or both of the metals as appropriate shall be electroplated or finished in such a manner that the potential difference is reduced to within the required limits. Where practicable, the two metals may be insulated from each other by an approved insulating material or a coating of approved varnish compound.

b) Screws, nuts, springs, pivots, etc.

The use of iron and steel shall not be used in instruments and electrical relays unless otherwise approved. Steel screws, if approved for use, shall be zinc, cadmium or chromium plated. If plating is not possible due to tolerance limitations, the iron or steel shall be corrosion-resistant. All screws in timber shall be of dull nickel plated brass or of other approved finish. Screws for instruments, except those forming part of a magnetic circuit, shall be of brass or bronze. Springs shall be of corrosion resistant material such as phosphor-bronze or nickel silver.

c) Adhesives

Adhesives shall be impervious to moisture and resistant to growth of fungus and ravage by insects.

d) Rubber

Neoprene and similar synthetic compounds not subjected to deterioration under the climatic conditions of the Site shall be used for gaskets, sealing rings and diaphragms.

Variation from the above provisions may be permitted where tropical grade materials are not available provided the Plant is hermetically sealed.

e) Stray current protection

This is no stray current. Therefore, stray current protection is not required for the design.

1.9 Labels

Labels shall be provided to identify all items of equipment, circuits, cables and where applicable, current rating of fuses and setting of relays, Labels on the exterior of equipment shall be clear perspex, reverse engraved, filled flush with black (or red as suitable) filling and the back portion painted the same colour as the equipment. Labels shall be attached by means of machine screws and nuts or machine screws driven into drilled and tapped holes.

2.0 ELECTRICAL

2.1 Earthing

Each of the Plant in or on which is fitted any electrical equipment shall be provided with an earthing terminal, suitable for connection by means of copper strip or of stranded copper conductor to the earthing system. The provisions for earthing shall be such that no reliance is placed on the conductivity of metal to metal joints without the use of special connectors.

2.2 Electrical Insulation

All insulating materials shall be suitably finished so as to prevent deterioration of their qualities under the specified working conditions.

Ebonite, synthetic resin-bonded laminated material and bituminized asbestos cement-bonded panels shall be of a suitable quality selected from the grades or types specified in the appropriate BS.

All cut or machined surfaces and edges or resin-bonded laminated materials shall be cleaned and sealed with an approved varnish as soon as possible after cutting.

Instruments, apparatus and machine coil windings, including wire wound resistors, with the exception of those immersed in oil or compound, shall be thoroughly dried in a vacuum or by other approved means and then immediately impregnated through to the core with an approved insulating varnish. Varnish with a linseed oil base shall not be used. Coils which cannot be varnish impregnated shall be impregnated with an approved wax compound. Paraffin wax or compounds containing paraffin wax shall not be used. The coils shall be covered before and after impregnation with a lapping of cotton or silk, or thread in the case of coils too narrow for tape, or covered by a sheet of suitable synthetic material. The impregnated coils shall finally be covered with an impervious enveloping varnish or given a dip coat of wax depending on whether they are varnish or wax impregnated. Coils impregnated with compound may be finished with compound sheet or tape.

Paper or other material of a hygroscopic nature shall not be used to cover coils. Where inter-leaving between windings in coils is necessary, the best thoroughly dried manila paper which permits penetration by the insulating varnish or wax shall be used.

The insulation of all machine windings, solenoids terminal boards, and the like, other than those immersed in oil or compound, shall be of BS EN 60085:2008, Class B materials unless otherwise specified.

All windings of machines shall be adequately braced and laid in micanite slot linings suitably protected by an approved non-hygroscopic material.

2.3 Electrical Instruments and Meters

All electrical instruments and meters shall comply with BS EN 60051-1:1999 and, unless otherwise specified, shall be of industrial grade accuracy. Three-phase power measuring instruments shall be of the 3-phase unbalanced load pattern wherever the current and voltage referenced permit.

Unless otherwise specified, all indicating and recording instruments shall be of the flush-mounting pattern with dust and moisture-proof covers.

Instrument dials shall not be less than 96mm x 96mm and shall be white with black markings unless otherwise approved.

Scales shall be of such material that no peeling or discolouration will take place with age under humid tropical conditions.

The movements of all electrically actuated instruments shall be of the dead-beat type.

Wherever necessary, instruments shall be provided with readily accessible zero adjustment.

All integrating watt-hour meters shall be of an approved switchboard pattern coloured black unless otherwise specified, and selected to give the grade of metering specified. They shall be single directional and shall be fitted where required with suitable contacts for DC impulsing.

Meters shall be calibrated to the appropriate grade in BS EN 62053-11:2003 and due allowance shall be made in such calibration for the errors in the instrument transformers to be used in service.

Ammeters shall be fitted with maximum demand indicators.

2.4 Small Wiring

All control-panel wiring and secondary wiring in circuit breakers, motor starters, control gear and the like shall be carried out in a neat and systematic manner with cables supported clear of the panels and other surfaces at all points to obtain free circulation of air.

In all cases, the sequence of the wiring terminals shall be such that the junction between multicore cables and the terminals is affected without cross over. Insulating bushes shall be provided where necessary to prevent the chafing of wiring.

All panel wiring shall conform to Type A or Type B of BS 6231, as appropriate. The conductors shall have a minimum cross sectional area equivalent to 7 strands of 0.67mm diameter.

Wire colours shall comply with the following:

Colour of Wire	Circuit Particulars
Red	Red-phase connections in current and voltage transformer circuits only.
Yellow	Yellow-phase connections in current and voltage transformer circuits only.
Blue	Blue-phase connections in current and voltage transformer circuits only.
Green and Yellow	Connections to earth.
Black	AC neutral connections, earthed or unearthed, connected to the secondary circuit of current and voltage transformers.

Grey	Connections in DC circuits.

Wiring diagrams must indicate wire colours. For back-wired panels, all diagrams shall be as viewed from the back of the panel. For front-wired panels, all diagrams shall be as viewed from the front. Wiring diagrams must state the highest number in any group.

All wires shall be fitted with numbered ferrules at each termination. At points of interconnection between wiring where change of numbering cannot be avoided, double ferrules shall be provided. Such points shall be clearly indicated on the wiring diagrams.

The ferrules on all wiring directly connected to circuit-breaker trip coils, tripping switches and the like shall be of a colour, preferably red, different from that of the remainder and marked "trip".

Wires shall not be teed or jointed between terminal points.

Bus wiring between control panel and the like shall be provided and shall be fully insulated and completely segregated from the main panel wiring.

All metallic cases of instruments, control switches relays and the like mounted on control panels or in cubicles, steel or otherwise, shall be connected by means of bare copper conductors of not less than 4mm2 in cross-section to the nearest earth bar.

2.5 Fuses and Links

All fuses and links associated with electrical instruments, protection and control circuits shall be of approved type and grouped as far as possible according to their functions and clearly labeled both on the panels and associated wiring diagrams.

Fuses and links shall be connected to enable all or any of the control circuits to be isolated for maintenance purposes.

Fuses and links associated with tripping circuits shall preferably be mounted on the outside of the control panels in approved positions, whilst the remainder shall be internally mounted.

All fuses shall be high rupturing capacity (HRC) cartridge type in accordance to BS 88, with class ‘Q’ fusing factor. Rewireable fuses shall not be accepted.

Carriers and bases for fuses shall be black.

2.6 Control Switches and Pushbuttons

Control switches for electrically operated circuit breakers shall be pistol-grip type arranged to operate clockwise when closing the circuit breakers and anti-clockwise when opening them. They shall be designed to prevent accidental operation and interlocked to prevent two successive operations in the “close” direction.

Switches for the other apparatus shall be operated by shrouded pushbuttons or handles of the spade type, the pistol-grip type being restricted for circuit breaker operations only. Control, reversing selector, and test switches shall be mounted, constructed and wired so as to facilitate maintenance of contacts without the necessity for disconnecting wirings.

Control switches for circuit breakers and for motor-operated setting devices shall be non-locking type with spring return to the 'neutral' position, and such control switches shall be controlled by independent springs. Contact springs shall not be used alone.

All pushbuttons shall be non-retaining type made of non-hygroscopic material, non-swelling and fitted to avoid any possibility of sticking.

The contacts of all switches and pushbuttons shall be strong, silver- plated, self-cleansing when operated so as to provide a reliable below-resistance path even at low voltage.

All control switches shall be provided with labels complying with Clause 1.9 of these Specifications, in addition to clear indication as to the direction of each operation, for example, "open", "close", "raise" and "lower".

2.7 Indicating Lamps and Fittings

Indicating lamps fitted to the facias of switch and instrument cubicles or panels shall be adequately ventilated. Back-indicating lamps shall be easily removed and replaced from the front of the panel by manual means not requiring the use of extractors.

The bezel of metal or other approved materials holding the lamp glass shall be of an approved finish and easily removable from the fitting so as to permit access to the lamp and lamp glass.

The lamps shall be installed in an accepted standard form of lamp holder. The rated lamp voltage shall be at least 4% in excess of the auxiliary supply voltage, whether AC or DC. Alternatively, low voltage lamps with series resistors shall be acceptable.

The lamps shall be of standard colour of red, green, blue, white and amber and shall be in the glass and not on applied coating. Transparent synthetic materials may be used instead of glass.

All lamp colours shall conform to the following:

Red	-	energized or operative position
Green	-	unenergized or inoperative position
Amber	-	fault or abnormal condition
White	-	healthy or normal condition
Blue	-	signal used with label

2.8 Auxiliary Switches

Each Plant shall be equipped with all necessary auxiliary switches, contactors and mechanisms for indication, protection, metering, control, interlocking supervisory and other services. All auxiliary switches shall be wired up to a terminal board on the fixed portion of the plant, whether they are in use or not.

All auxiliary switches and mechanisms shall be mounted in approved accessible positions clear of the operating mechanisms and shall be protected in an approved manner. The contacts of all auxiliary switches shall be strong and shall have a positive wiping action when closing.

2.9 Anti-Condensation Heaters

Any major item of electrical equipment which are liable to suffer from internal condensation due to atmospheric or load variations shall be fitted with heating devices suitable for electrical operation at 50Hz single-phase 230V AC of sufficient capacity to raise the internal ambient temperature by 5ºC. The electrical apparatus so protected shall be designed so that the maximum permitted rise in temperature is not exceeded if the heaters are energized while the apparatus is in operation. Where heaters are fitted, a suitable terminal box and control switch, with indicating lamps, shall be provided and mounted in an accessible position. All such equipment, whether fitted with a heating device or not, shall be provided with suitable drainage and shall be free from pockets in which moisture can collect.

2.10 Cable Boxes and Glands

Electrical equipment shall be fitted with approved cable boxes and brass glands, complete with all necessary fittings.

Provision shall be made for earthing the body of each cable box.

Where cable boxes are provided for 3-core and 4-core cables, the sweating sockets on the two outer phases shall be inclined towards the centre to minimize bending of the cable cores.

For XLPE/PVC insulated and sheathed power cables, controlled brass compression glands of an approved type shall be provided. Where such cables have armouring and an outer sheath, the gland shall be of the type which grips each sheath and the armouring separately. Glands shall be arranged to project at least 25mm above the gland plate to avoid moisture collecting in the cable circuit.

2.11 Contactors

Contactors shall comply with BS EN 60947-4-1 with uninterrupted ratings UR mechanical duty Class II and making and breaking category AC3, as appropriate.

Both the main and auxiliary contacts shall be renewal type, solid copper, hard silver-faced shrouded and designed to ensure effective freedom and contact bounce and adhering of the fixed and moving portions of the magnet assembly. Auxiliary contacts shall be provided for control and indication. Contactor coils shall be fully tropicalized and wound for continuous operation at phase voltage with Class ‘E’ insulation as specified in BS EN 60085:2008.

In cases where contactor-control current may be energized by interlocking connection with other circuits, conspicuously mounted warning labels or other approved means shall be provided to ensure that such interlocking connections are isolated by the operation of the appropriate selector switch to the current position. Pairs of contactors for reversing switches shall be electrically interlocked.

Changeover contactors shall be interlocked both mechanically and electrically.

The contactor shall be located within the enclosure so that upon making or opening of the contactor under normal or fault conditions, damage will not be caused to other equipment and wiring within the enclosure.

Contactors equipped with both local and remote control shall have local/remote changeover switches capable of being locked in either position.

2.12 Protective and Control Relays

All relays shall be of the heavy duty BPO 3000 pattern and fully tropicalized.

Relays which provide different modes of operation and are common to one particular circuit shall be grouped conveniently in a dust-proof metal cabinet with removable hinged covers giving access for adjustment and clearing without dismantling the relay.

Each relay shall be provided with clearly inscribed labels describing its application and rating in addition to the general purpose labels.

Means shall be provided on the relay panels for the testing of protective relays.

2.13 Moulded Case Circuit Breakers (MCCB)

All moulded case circuit breakers shall comply with the requirements of BS EN 60947-2:2006+A2:2013 and shall be of the current limited type. Unless otherwise stated, the AC rated short-circuit capacity shall be:

a) 10kA for standard rated currents up to and including 30 amp.

b) 22kA for standard rated currents up to and including 400 amp.

c) 45kA for standard rated currents greater than 400 amp.

The MCCB shall incorporate a time delay device to ensure that it will tolerate harmless transient overload unless this is well in excess of 25% of its rated value for a sustained period.

The MCCB shall be able to isolate the fault instantaneously for short circuit current of the order of six to ten times the normal load current.

MCCB shall employ silver tungsten contacts of the high pressure, butt type, ensuring cool operation at full load and shall be equipped with de-ionizing arc chutes for the rapid extinction of arcing occurring during overload operation. The breaker shall be operated by a toggle- type handle lockable at “Off” position and having a quick-make, quick- break mechanisms and shall be mechanically trip free from handle to ensure that the contacts cannot be held closed against short circuit and abnormal current. Visual indication of the “OFF”, “TRIPPED” and “ON” positions, phase identification colours and appropriate labels shall be provided and shall be able to incorporate auxiliary switch under-voltage release and shunt-trip unit, if required.

Sample of MCCB shall be submitted to the The-Contractor or his representative for approval before fabrication of switchboards.

Units shall be complete with bolted-type neutral link, links for both supply neutral connection and earthing, screening shutters actuated automatically with the circuit breaker isolated and withdrawn and capable of padlocking in such position, SN auxiliary switches independently adjustable for N/O or N/C automatic release coils and manual tripping device.

2.14 Miniature Circuit Breakers

Miniature circuit breakers (MCB) shall comply with BS EN 60898-1:2003+A13:2012 and shall have breaking capacity not less than 10kA (rms) and of B-type with Class 3 energy limiting characteristics.

The mechanism of the MCB, shall provide positive closing and trip-free action. On the dolly of the MCB, the words 'ON' and 'OFF' shall be clearly engraved such that only one indication is visible at any one time.

The MCB shall incorporate a thermal and/or magnetic overload unit which shall be sealed at the factory.

The contacts shall be of high conductivity copper with silver plated tips.

2.15 Air-Circuit Breakers (ACB)

Air-circuit breakers shall be certified by an independent short-circuit testing authority as being suitable for a rated short-circuit current of 41kA with a short-time rating of 3 seconds at 415V. The ACB shall be manufactured in accordance with BS EN60947-2.

Units shall be capable of being independently and manually operated and of the horizontal draw-out isolation type so arranged that they may be completely isolated from the incoming supply and busbars except that secondary circuits shall not be broken with the circuit breaker in the isolated position in order to permit test tripping and the like.

Closing mechanisms shall be of the trip-free type and incorporate "ON/OFF" and "ISOLATED/PLUGGED" indicators and mechanically interlocking to prevent:

a) Withdrawal or plugging of the circuit breaker in the closed position.

b) Closure unless either fully plugged or fully isolated.

c) Opening of cubicle door until breaker is isolated.

d) Plugging-in until the cubicle door has been closed and locked.

Units shall be complete with bolted-type neutral link, with links for both supply, neutral connection, and earthing; screening shutters actuated automatically with the circuit breaker isolated and withdrawn and capable of padlocking in such position; six auxiliary switches independently adjustable for normally open (N/O) or normally closed (N/C); automatic release coils; and manual tripping device.

2.16 Current and Voltage Transformers

Current and voltage transformers shall comply with BS EN 61869-2:2012 and BS EN 61869-3:2011 as appropriate. They shall be housed or accommodated to suit their particular duties. All current and voltage transformers shall be capable of withstanding short circuit current specified for switchgear assembly.

Secondary windings shall be wired to front-of-panel test terminal boards and earthed at one point in the circuit, to facilitate secondary injection tests.

All transformers shall be provided with an identifying label giving type, ratio, class, output and serial number.

2.17 Overcurrent and Earth Fault Inverse Time Protection

Relays shall be of the microprocessor based, inverse time overcurrent type.

Overcurrent elements shall be supplied with adjustable settings for both operating current and time, the design of the relays being such that the adjustment can be carried out on-load. The range of current setting adjustment for phase faults shall be 50% to 200% of the rated full load and time setting multiplier shall be over the range of 0.05 to 1.0. The current/time characteristics of the relays shall be in accordance with the four inverse time characteristics of IEC 255-4.

Inverse time earth fault elements shall comply with the foregoing but shall be continuously adjustable from 10% to 40%.

Earth leakage relay ELR shall be of the type suitable for use on a 230/400V, 50Hz a.c. system and up to ambient temperature of 40 °C comply with BS EN 61008-1:2012+A11:2015 and 61008-2-1. ELR shall be provided with test button for simulation of a fault, earth leakage LED indicator and protection against nuisance tripping due to transient voltage and d.c. sensitive. For adjustable sensitivity and time delay type, selectivity range for sensitivity shall be 30mA, 100mA, 300mA, 500mA and 1000mA and the time delay selectivity range of 0 s to 1 s. ELR shall incorporate with matching balanced core current transformer and shunt trip coil for the circuit breaker to which it controls the tripping shall also be provided.

The microprocessor based protection relays shall be rated 230V/400V and operating voltage shall be in a range from 90V to 250V. The relays shall be housed in robust panel flush mounting case to IP 54 and shall be fully tropicalised and suitable to be used up to an ambient temperature of 50 °C and relative humidity of 95%.

2.18 Residual Current Operated Circuit Breakers

Residual current operated circuit breakers without integral overcurrent protection (RCCB) and residual current operated circuit breakers with integral overcurrent protection (RCBO) shall be current operated functionally independent of line voltage type, suitable for use on a 230/400V, 50Hz. a.c system and up to an ambient temperature of 40 °C. RCCB shall comply with BS EN61008-1 and 61008-2-1 and RCBO shall comply with BS EN 61009-1:2012+A12:2016 and 61009-2-1. They shall be of either two-pole or four-pole type as indicated in the Drawings. The rated current and the rated residual operating current of the RCBO shall be as specified in the Drawing. For RCBO, protection against overcurrent shall be B-type with Class 3 energy limiting characteristic comply with BS EN 60898, and shall have breaking capacity of not less than 6 kA.

RCCB and RCBO shall provide resistance against nuisance tripping due to an impulse voltage or transient overvoltage.

Test push button and visual indication for ‘ON’ and ‘OFF’ or ‘I’ and ‘0’ shall be provided. They shall be equipped with screw clamping type of cable terminals, which shall be covered by moulded phenolic plastic with knockouts for cable entry.

2.19 Digital Power Meter

Sub-Contractor shall provide a Digital Power Meter (DPM) device (where necessary) that is suitable for MV and LV application as per drawings. It shall have the features, functions and display as per specification as describe below.

The DPM shall be of the type with microprocessor - based capable of measuring and displaying all the electrical quantities of the Network including:

a) 3 Phase Current (L1 - L2 - L3, I_{min} & I_{max}, summation value of 3 Phase Current)

b) Voltage (Phase to Neutral, Phase to Phase, U_{min} & U_{max}, summation value of 3 Phase Voltage)

c) Power with Average and peak values (KW, KVAR, KVA)

d) Power Factor with average 3 phase and individual phase measurement

e) KWH & KVARH with total and partial reading

f) Harmonic for Current and Voltage in percentage

g) Maximum Demand on Power with Average & Peak Value

h) Neutral Current and Hour Meter

The DPM shall be of a standalone basic unit and can coupled and compatible to use with various types of serial communication interfaces such as RS485 (OPC / JBUS / MODBUS / Lonwork / MBUS / BACNET / PROFIBUS) for data collection at remote terminal of data logger and it shall be connected with screen cable (3 wires) housed in metallic conduits to prevent inferences from power cables.

Apart from the serial communication, the DPM shall also have the available facilities to ADD-ON optional Plug-In Modules for monitoring such as Alarms, Neutral Current, I/0 2 Inputs SPST - 2 Outputs OR I/0 2 Inputs 12.24 Vdc - 2 Outputs where applicable.

The programming parameters shall be provided by touch button keyboards at the front of DPM for easy access and the programming access shall be protected by enabling code to avoid unauthorized attendance. The DPM shall have an EPROM memory facility to hold data's and configured parameters in the event of power loss.

The Digital Power Meter shall be tested and conformed to the following standards and a copy of Test Report shall be submitted:

Description	Standard
Emission & immunity test	EN62052-11
Emission / radio disturbance	EN55022/CISPR22
Impulse voltage test 6kV 1.2/50us	EN61010-1
AC Voltage test 4kV rms value 50Hz / 1 min	EN61010-1
Insulation voltage rating 300V (Phase - Neutral)	EN61010-1
Energy accuracy test class	EN62053-21 & 23
Electromagnetic compatibility (EMC)	EN61000-4-6
Protection degree - IP54 front frame & IP20 terminals	EN60529
Pollution degree	EN61010-1

The DPM shall have the facilities in programming and setting different types of network system and parameter, display for back lighting, environmental conditions, housing and measured & accuracy to meet the following specifications: -

a) Programmable Parameters

ITEM	PARAMETERS	REQUIREMENT
1	3 Phase 3 / 4 Wire network, unbalanced load (selectable)	Voltage range between 0 - 600VAC without distortion in measurement
2	Aux. Supply	80 - 265VAC and 110 - 300Vdc OR 11 - 60Vdc as per drawings
3	Input Voltage	0 - 600V Phase to Phase
4	Input Current	1A and 5A programmable
5	Frequency range	47 - 63Hz
6	External VT & CT ratios	Programmable VT primary ratio up to 150kV and CT ratio up to 50,000A/5A OR 10,000A/1A
7	Energy count for output pulse weight	10WH to 10MWH - programmable

b) Display

ITEM	PARAMETERS	REQUIREMENT
1	Type of display	LCD with Back lighting with automatic reduction. OFF after 20sec that keyboard is not use.
2 a) b)	No. of display points / digits for: Electrical quantities Energy count (KWH & KVARH)	 4 digits - digit Height : 12mm 8 digits - digit Height : 8mm

c) Measurement of:

ITEM	PARAMETERS	REQUIREMENT
1	Electrical quantities	4 quadrants
2	Energy count	4 quadrants
3	Measurement reading update	1.1sec

d) Environment Conditions

ITEM	PARAMETERS	REQUIREMENT
1	Specific operating temperature range	- 5 to 55ºC
2	Limit temperature range for storage & transport	- 25 to 70ºC
3	Yearly average relative humidity	≤ 95%

e) Housing

ITEM	PARAMETERS	REQUIREMENT
1	Type of material	self-extinguish polycarbonate
2	Front frame	96 x 96mm
3	Type of mounting	Flush
4	Protection degree	IP54 front frame, IP20 terminals
5	Weight	285gms

f) Measured Value and Accuracy

ITEM	PARAMETERS	REQUIREMENT
1	Phase & link voltage - min & max values - summation of 3 phase values	0.2%
2	Phase current - min & max values - summation of 3 phase values	0.2%
3	Neutral current	0.5%
4	Frequency	0.15Hz
5	Power factor 1 phase & 3 phase	0.5%
6	Active, reactive & apparent power	0.5%
7	Active phase power 1 phase & 3 phase	0.5%
8	Active Energy (Positive & Negative measurement)	0.5%
9	Reactive Energy (Positive & Negative Measurement)	2%
10	Max. demand for average & peak value (KW, KVA & KVAR) (Demand integration period programmable from 5 to 60 mins.)	0.5%
11	Total harmonic distortion for each phase voltage	0.5%
12	Total harmonic distortion for each phase current	0.5%

2.20 Ammeters

Ammeters shall be dial flush mounting moving iron spring controlled (MISC) type suitably scaled over 240 degrees.

2.21 Voltmeters

Voltmeters shall be dial flush mounting type scaled from 0V to 500V over 240 degrees.

2.22 Kilowatt-hour Energy Meter

All kilowatt-hour (kWh) energy meter shall be contained in dustproof cases. All metal bases and frames shall be earthed by conductors of not less than 2.5mm² cross-sectional area, except where they must be insulated for special requirements. All kWh energy meters shall be mounted on the front of relay panels at a convenient height so as to be accessible for inspection and reading.

All kWh energy meters shall be of the flush-mounted draw out type.

The kWh energy meter shall be of induction type and suitable for 400V, 3 phase, 4 wire, 50 Hz system with the voltage coils directly connected to the system with fuse protection and the current coils via the CTs.

The kWh energy meter shall comply with the requirements as specified in IEC 62521-11:2003 and the accuracy shall not be affected by phase sequence reversal.

The kWh energy meter shall have a 6-digit cyclometer reading with the accuracy to the nearest 1 kWh.

All kWh energy meters shall have remote indication facilities. They shall be able to transmit pulses at 1 kWh intervals, via volt-free contacts.

The kWh energy meter shall be suitable for 3-phase inductive load with a power factor from 0.5 to 1.

END OF SECTION

ELVS - LV SWITCHBOARD & SWITCHGEARS

CONTENTS

ELVS - LV SWITCHBOARD & SWITCHGEAR

1.0 GENERAL REQUIREMENTS

In complying with the requirements of this Specification, the design and workmanship shall conform to the best current engineering practice. Each of the several parts of the Equipment shall be of the manufacturer's standard design while meeting the requirements of this Specification. All similar parts of the Works shall be interchangeable.

The essence of design shall be simplicity and reliability to give long continuous and efficient service with low maintenance cost. Particular attention shall be paid to internal and external access in order to facilitate inspection, cleaning and maintenance.

The design, dimensions and materials of all parts of the Works shall be such that they will not suffer damage as a result of stresses under the most severe service conditions.

Fully detailed specification of the parts of the equipment shall be submitted with the factory working drawings and erection drawings describing particularly the materials to be used.

The materials used in the construction of the Equipment shall be of the highest quality and selected particularly to meet the duties required of them. Materials, which may be liable to attack by termites or other insects, shall not be used. Detachable parts shall be constructed to avoid adhesion due to any cause.

The Equipment shall operate without undue vibration and with the least possible amount of noise such that nuisance is not created.

The Equipment shall be designed to minimize the risk of fire and any damage which may be caused in the event of fire.

The Equipment shall be designed to prevent ingress of all vermin, accidental contact with live parts and to minimize the ingress of dust and dirt.

Detailed planning and co-ordination by Sub-Contractor will be necessary to achieve a fully coordinated and efficient installation particularly with regard to sequence of erection. Precise positioning and handling of all items forming the total system having due regard to proper access for ease of maintenance and replacement shall be undertaken.

2.0 CODE AND STANDARDS

This section shall be designed and constructed in accordance with the latest revision of the following standards and the appropriate BS/IEC;

Standards	Document Titles
BS EN 61439-2:2011	Electrical insulation. Thermal evaluation and designation
BS EN 61439-5: 2015	Low-voltage switchgear and controlgear assemblies. Assemblies for power distribution in public networks

Standards	Document Titles
BS EN 13601:2021	Copper and copper alloys. Copper rod, bar and wire for general electrical purposes
BS EN 60947-3:2009+A2:2015	Low-voltage switchgear and controlgear. Switches, disconnectors, switch-disconnectors and fuse-combination units
BS EN 61439-6:2012	Low-voltage switchgear and controlgear assemblies. Busbar trunking systems (busways)
BS EN 60947-4-1:2019	Low-voltage switchgear and controlgear. Contactors and motor-starters. Electromechanical contactors and motor-starters
BS EN 60871-4:2014	Shunt capacitors for AC power systems having a rated voltage above 1 000 V. Internal fuses
BS EN 60831-1:2014	Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1 000 V. General. Performance, testing and rating. Safety requirements. Guide for installation and operation
BS 6093:2006+A1:2013	Design of joints and jointing in building construction. Guide
IEC 60831-1:2014	Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1 000 V - Part 1: General - Performance, testing and rating - Safety requirements - Guide for installation and operation
IEC 60076:2015	Power transformers
IEC 60076-7	Power transformers – Part 7: Loading guide for oil-immersed power transformers
IEC 60211	Maximum demand indicators, Class 1.0
IEC 61111:2009	Live Working – Electrical Insulating Matting
BS381C / BS 4800	Specification for colours identification, coding and special purposes.
IEC 60529 / BS EN 50529	Degrees of protection provided by enclosures (IP Code)

3.0 RATED VOLTAGE

The rated voltage of switchgear and distribution boards shall not be less than 400V AC between poles and 230V to earth.

4.0 MAIN SWITCHBOARDS

The main switchboard shall be modular in construction consisting of a number of individual cells bolted together to form a free standing self-supporting structure and shall comply with BS EN 61439-2:2011. Unless otherwise specified, the switchboards shall be fully segregated to IEC 61439-2 Form 3B and comply with the safety requirements of this standard. Outdoor switchboards shall also comply with BS EN 61439-5: 2015 and Ingress Protection. The

framework shall be not less than 2.5mm thick and fabricated from high strength welded and bolted U-shaped steel sections. The rigid construction shall be designed to withstand without sag or deformation, the loads likely to be experienced during normal operating, maintenance or maximum fault conditions. The degree of protection shall be IP41 (indoor) and IP54 (outdoor) degree to IEC 60529 and BS EN 60529.

Unless otherwise specified, the switchboard shall be fabricated from sheet steel of not less than 2.0mm thick with turned and boxed edges so formed as to provide a clean, flush and pleasing appearance and rigid construction without the use of welded cross struts. The removable cladding on the top and sides shall be of heavy gauge sheet steel.

Fixing of the top and rear shall allow the two panels to be blown off so as to relieve the pressure built up within the cubicle, during an explosion.

Access to control equipment inside the cubicles and the rear shall be provided by means of suitable doors (with car door type handle) and integral cylinder locks which, except in the case of distribution boards, shall be mechanically interlocked with the controlling switch to prevent the door being opened when the switch is in the 'ON' position. Door hinges shall be concealed. Doors shall be earthed to earthing terminals.

The various cubicles housing the respective control units shall be grouped to form a multi-tier arrangement and a further part shall where possible constitute a cabling and wiring chamber of appropriate dimensions in which terminal boards, cable boxes and gland plates shall be located.

The interior of each cubicle shall be of matt white finish and the whole unit shall be proofed against dust and vermin. The front, top and back of all cubicles shall be finished with semi-gloss beige paint. All parts to be painted shall first be degreased, etched, primed and then coated with epoxy finish. Where cables pass through the bottom plate of the switchboard, suitable vermin plates and hardwood bush or cable glands shall be provided to ensure that this proofing is maintained. Covers shall be provided with grommets to ensure exclusion of dust and dirt. Precautions shall be taken to prevent overheating through hysteresis and eddy current losses.

Busbars and busbar connections shall be constructed in accordance with the requirements of IEC 61439-2. Busbars shall be of solid rectangular bars sections made of hard drawn high conductivity tinned copper and shall conform to BS 159:1992 and BS EN 13601:2013. The short-time withstand current rating shall be 50kA for 1 second/ 43.1 kA for 3 seconds at 400V. The complete busbars assembly shall be capable of carrying continuously the specified current without overheating and shall be rigidly mounted on a non-hygroscopic insulator so as to withstand any mechanical force to which they may be subjected under maximum fault condition of not less than 50kA for 1 second. Switchboards shall be manufactured to ASTA or KEMA type-tested boards and the certificates shall be submitted for The Contractor or his representative's approval.

Busbars shall be painted/insulation sleeves red, yellow, blue or black at appropriate points to distinguish the phases and neutral. The busbars shall be arranged in a horizontal plane and in the order red, yellow, blue and neutral from back to front. On vertical planes, connections shall be red, yellow, blue and neutral from left to right, viewed from the front of the panel. The neutral busbar shall be of the same size as that of the phase busbars.

An earthing busbar of not less than 50mm by 6mm shall run the full length at the base of the switchboard and shall be painted green and yellow (twin-coloured) at appropriate points.

For connections between switching devices, busbars and terminals, PVC (polyvinyl chloride) insulated cables may be used for circuits of up to and including 150A rating. For ratings above 150A, PVC insulated tinned copper busbar interconnections of appropriate cross-sectional area shall be used.

All connections shall terminate in sweating lugs, copper or brass mechanical clamps of approved types and fastened to busbars with suitable brass bolts, brass washers, steel spring washers, brass nuts and lock nuts.

Incoming and outgoing terminals, interconnecting PVC insulated busbars and PVC insulated cable interconnections shall be provided with suitable "Phase" and "Neutral" identification colours marked thereon, as required by the latest relevant BS. Coloured PVC sleeving shall be used for identification as far as possible but the use of coloured PVC adhesive tape for this purpose shall not be permitted.

Wherever PVC insulated cable interconnections are used, the cables shall be neatly bound to frame supports by means of PVC binding strips or clipped with PVC insulated copper saddles and brass screws. This shall also apply to all PVC insulated control and instrument wirings.

Suitable cable spacers and insulated bushes shall be provided for all cable entries and exits through metalwork.

In the case where no power factor correction equipment is provided, the main switchboard shall be so constructed that sufficient space is available to accommodate the cables and other accessories of power factor correction equipment that may be installed at a later stage.
Instruments, meters and relays located on the front portion of the switchboards shall be so positioned that as far as possible, each instrument, meter and relay is adjacent to the unit with which it is associated. All relays shall be heavy-duty pattern, unaffected by external vibration and capable of operating in any position. All meters, instruments and relays shall be fully tropicalized.

All secondary wiring shall not be less than 1.5mm2 cross-sectional area. The wires shall be insulated with PVC and shall be fixed securely without strains by cleats of the compression type. For purpose of identification, different colours shall be provided to distinguish the various circuits and each conductor shall terminate at an approved type of terminal block placed in an easily accessible position for testing at Site with coded ferrules of an approved type at both ends of each conductor. No connection or soldered joints will be permitted in the wiring.

One number anti-condensation heater shall be installed for every two sections of the switchboard. Each heater shall be complete with automatic thermostat control, ON-OFF switch and indicating lamp.

A compartment for accommodating spare MCCB's shall be built-in with each freestanding switchboard. A total of additional 30 percent of spare compartments for future extension to the switchboard shall be provided.

5.0 METERING PANEL

Metal-clad wall-mounted metering panels (where necessary) shall be installed at positions indicated in the Drawings. Sub-Contractor shall make provision in the panels for the installation of the meters. Sufficient length of cable shall be provided for termination of cables at the meters.

6.0 DISTRIBUTION BOARD

All distribution boards and sub-switchboards shall be supplied and installed at the various positions indicated in the Drawings. The boards shall be provided with Miniature Circuit Breakers (MCB) and it shall be so designed that the MCB can be replaced without disturbing or removing the adjacent units and busbar connectors. The interior of the panel shall be provided with a removable internal shroud, giving access to the MCB dollies, but covering the remainder of the interior for neat appearance after wiring. The internal shroud shall be of the same finish as the exterior of the board. Labels for phase and circuit identification and current ratings shall be fixed on this internal shroud either above or below the dollies.

On the outside face of each board cover, a black Perspex label with the number of the distribution board as indicated on the schematic diagram and engraved in white on chrome-yellow lettering shall be provided and fixed thereon. For TPN type distribution boards, an additional white Perspex label on each board, bearing the letters: "DANGER 400V, 3-PHASE SUPPLY" engraved in red colour thereon shall be installed.

All distribution boards shall be fitted with suitable means for terminating incoming and outgoing cables and final sub-circuit wiring. Sufficient gutter space shall be provided on the sides to clip the final sub-circuit wiring. The neutral and earth bus bars shall be provided with the same number of terminals as there are ways.

The distribution board shall be of a totally enclosed type construction and be suitable for installation on walls or be recessed in walls of buildings. All boards shall be rated for the intended voltage and be in accordance with the relevant BS. All exterior and interior steel surfaces of the board shall be properly cleaned and epoxy finished with approved grey over a rust-inhibiting phosphate coating. The steel sheet used shall not be less than 2mm thick.

Busbars for the mains shall be of hard drawn high conductivity copper and sized in accordance with the relevant BS. Full size neutral busbars shall be provided. Busbars shall be braced throughout to conform to standard practice governing short circuit stresses in distribution boards.

All distribution boards shall be rated at not less than 120% of the specified and calculated loads. Spare ways of 30% spare capacity shall be installed with MCB's and be fully wired and labelled.

7.0 PHOTOCELL

Outdoor lighting shall be photocell switch controlled through a suitably rated latched contactor with time delay incorporated between each circuit to even out the switching peaks.

The photocell sensor must not be located in any shaded area. A manual by-pass switch shall be provided for every photocell switch.

The photocell switch shall be capable of at least one “ON” and one “OFF” operation per day. The photocell switch shall operate load contactors of adequate continuous rating to cater for the loads.

8.0 AIR CIRCUIT BREAKER

Air circuit breakers (ACB) shall be of withdrawable metalclad, flush mounted, horizontal drawout isolation and air break type suitable for installing on cubicle type of switchboard. They shall be three or four poles type as specified and shall comply fully with MS IEC 60947-1 and 60947-2. They shall be ASTA, KEMA or other accredited laboratories certified for minimum rupturing capacity, rated short time withstand current, (Icw) of 50kA at 400V for 1 second or otherwise specified.

They shall consist of quick-make, quick-break, mechanically and electrically trip free mechanism arranged to give double break in all poles simultaneously. The closing mechanism shall be of stored energy type, either manually or electrically charged. Mechanical `ON' and `OFF' or 'I' and 'O' indicators shall be provided. The tripping mechanism shall be equipped with push button for independent manual tripping and shall be stable and not being opened by shocks.

Each pole of the circuit breaker shall be provided with an arc chute to extinguish the arc drawn between the breaker contacts each time a breaker interrupts current, and interpole barriers to reduce arcing time for rapid deionization of the arc and guard against flash over. The contacts shall be renewable type.

The operating mechanism and carriage shall have the following positions: -

a) Service- In this position the main and control contacts are engaged.

b) Test - In this position the main contacts are isolated but the control contacts are still engaged. It shall be possible to check the correct operation of the control circuits without energising the main circuit.

c) Isolated - Both main and control contacts are isolated.

They shall be provided with marking to show the breaker positions with facility for padlocking the carriage in the Test and Isolated positions. They shall be equipped with the following interlock devices: -

a) Prevent withdrawal of breaker while the breaker is in closed position.

b) Prevent closure of breaker while the carriage is in any position between `fully isolated' and `fully home'.

The arrangement of the busbar connections shall be such that with the circuit breaker withdrawn, the live parts shall be protected, either by suitable shrouding or lockable shutters.

Minimum four numbers (2 -Normally-Open, 2-Normally-Close) double break type auxiliary contacts shall be provided.
Mechanical interlocks and/or electrical interlocks, where specified, shall be provided. Mechanical interlock shall be of code key type, arranged to mechanically operate the trip mechanism latch so that the breaker can only be closed when the key is trapped in the lock. Electrical interlock shall be controlled by means of operation of auxiliary switches of another breaker designed to cut out the closing coils and mechanism of the parent breaker.

Where used as bus-coupler, they shall be of 4 pole type and provided with electrical and/or mechanical interlocks as required so that it is not possible for the coupler to close with its associated main incoming supply breakers closed.

Where used as incoming feeder from supply source (either from transformer, generator set or coupler), they shall be of 4 pole type.

The neutral of the 4 pole type ACB terminals shall be of the same size as the phase.

The frame of ACB shall be bonded to the switchboard earthing bar using of 3mm x 25mm tinned copper tape.

9.0 MOULDED CASE CIRCUIT BREAKER

Moulded case circuit breakers (MCCB) shall have the number of poles as specified in the Drawings and/or Bill of Quantities. They shall comply with MS IEC 60947-1 and MS IEC 60947-2. They shall be fully tropicalised and suitable to be used up to an ambient temperature of 40oC, enclosed in glass-reinforced polyester moulded case and suitable for use on 230/400V, 50Hz. a.c. supply system.

They shall be of the quick-make, quick-break type having manually operable toggle type handle. Permanent position indicators shall be provided to show status of the breaker. When tripping occurs, the handle shall be in the `trip' position midway between the 'ON' and 'OFF' or ‘I’ and ‘O’ position so as to provide positive indication of automatic interruption. The operating mechanism shall be non-tamperable. The MCCB shall have trip-free feature to prevent the breaker from being closed against fault conditions. Multipole MCCB shall have common-trip operating mechanism for simultaneous operation of all poles.

The tripping units shall be one of the following types: -

a) Thermal-magnetic type with bimetallic elements for inverse time-delay overload protection and magnetic elements for short circuit protection.

b) Solid state trip unit with adjustable overload protection and adjustable short circuit protection with or without adjustable time-delay.

An arc extinguisher shall be incorporated to confine, divide and extinguish the arc drawn between the breaker contacts each time a breaker interrupts current. The contacts shall be of non-welding type.

Unless otherwise specified in the Drawings and/or Bill of Quantities, the minimum rated ultimate short circuit breaking capacity (Icu) of the MCCB shall be 50kA rms at 400V for switchboards connected to transformer or Supply Authority's or Licensee’s incomer and 25kA for the subsequent switchboards.

The rated service short-circuit breaking capacity (Ics) shall be 100% of the rated ultimate short-circuit breaking capacity (Icu) at 400 volts for incoming feeder, and for all outgoing feeder Ics shall be 50% of Icu.

Unless otherwise specified the rated ultimate short circuit breaking capacity (Icu) for MCCB at Distribution Board shall be not less than 10kA at 230/400V and Ics shall not be less than 50% Icu at 230/400V.

If current limiting types of MCCB are used, they shall be equipped with current limiting device of either permanent self-resetting power fuse type or magnetic repulsion moving contact type.

The current limiting device shall coordinate with the normal trip mechanism so that all fault and overload currents occurring within the safe capability of the MCCB shall cause the MCCB to open, and all currents occurring beyond the capability of the MCCB shall cause the current limiting devices to operate.

If required, the MCCB shall have facilities for shunt trip, under-voltage/no-volt trip, externally connected earth fault protection, externally connected overcurrent protection etc.. They shall also have auxiliary contacts, accessories etc. for indication, alarm and interlocking purposes if necessary. In area where is specified, and door interlocking facilities to prevent the panel door from being opened to access to the MCCB in closed position, shall be provided.

Where used as incoming feeder from supply source (either from transformer and/or generator set), they shall be of 4 pole type.

10.0 MINIATURE CIRCUIT BREAKER

Miniature Circuit Breakers (MCB) shall be of the type approved by Suruhanjaya Tenaga and JKR.

Unless otherwise indicated in the Drawings and/or Bill of Quantities, (MCB) shall have breaking capacity not less than 6kA (rms) and of C-type with Class 3 energy limiting characteristics. They shall comply with MS IEC 60898-1 and/or MS IEC 60898-2, fully tropicalised and suitable for use on a 230/400V, 50Hz. a.c. system and up to an ambient temperature of 40oC.

They shall be quick-make, quick-break and trip free type complete with de-ion arc interrupters. The tripping elements shall be of thermal magnetic type with inverse time delay overcurrent and instantaneous short circuit characteristic. The response to overload shall be independent of variations in ambient temperature.

They shall be manually operated by means of toggle type handles having visual indication of whether the breaker is opened, closed or tripped. Multipole MCB shall be of all pole protected type and provided with common-trip mechanism for simultaneous operation of all the poles.
Where used as incomer, they shall be of 2 pole type.

11.0 RESIDUAL CURRENT DEVICE

Residual Current Device (RCD) shall be of the type approved by Suruhanjaya Tenaga and JKR.

RCD shall be residual current operated circuit breakers without integral overcurrent protection (RCCB) and residual current operated circuit breakers with integral overcurrent protection (RCBO) shall be current operated functionally independent of line voltage type, suitable for use on a 230/400V, 50Hz. a.c. system and up to an ambient temperature of 40°C. RCCB shall comply with MS IEC 61008 -1 and MS IEC 61008-2-1 and RCBO shall comply with MS IEC 61009-1 and MS IEC 61009-2-1. They shall be of either two-pole or four-pole type as indicated in the Drawings

and/or Bill of Quantities. The rated current and the rated residual operating current of the RCCB or RCBO shall be as specified in the Drawings and/or Bill of Quantities. Rated conditional short circuit current (Inc) shall be of minimum 6kA. For RCBO, protection against overcurrent shall of C-type with Class 3 energy limiting characteristic complying with MS IEC 60898-1 and MS IEC 60898-2. The breaking capacity shall not be less than 6kA.

RCCB and RCBO shall provide resistance against nuisance tripping due to an impulse voltage or transient overvoltage.

RCCB and RCBO shall be A or AC type unless otherwise specified.

Test push button and visual indication for 'ON' and 'OFF' or ‘I’ and ‘O’ shall be provided. They shall be equipped with screw clamping type of cable terminals, which shall be covered by moulded phonolic plastic with knockouts for cable entry.

12.0 FUSE SWITCHES AND SWITCH FUSES

All Triple Pole and Neutral (TPN) fuse switches and switch fuses shall be of 500V rating and the design shall feature a rigidly constructed enclosure made from sheet steel attractively finished in a durable high-gloss baked enamel of Light Grey No. 631 to BS 381C. They shall have engraved circuit identification attached to the exterior of the cover. The fuse switch shall have positive indication of the switch position which shall be given by a mechanical "ON" "OFF" indicator, driven by the moving contacts operating linkage, and clearly visible through a transparent bezel in the cover.

Access to the interior shall be through the front door which shall be interlocked in such a way as to prevent (a) the door being opened when the unit is in closed position, and (b) the inadvertent closure of the switch when the door is opened. Provision shall be made for the door interlock in (b) so that unauthorised personnel shall not be allowed access to the equipment.

Fuse switches shall be heavy duty, double air-break, quick makes and break pattern with fuse cartridges bolted onto the moving contacts complete with phase barriers, fully shrouded contacts and hard silver plated switch contacts. Switches shall be provided with adequate accelerating springs and a toggle action to ensure positive ON/OFF switching action independent of the operator, and in the event of a broken spring, the switch shall be able to be closed sufficiently to carry the rated normal current as required by BS EN 60947-3:2009+A2:2015.

The switch fuses and fuse switches shall be fitted with HRC fuse links. All TPN fuse switches and switch fuses shall fully comply with BS EN 60947-3:2009+A2:2015.

Unless specified in the Drawings and/or Bill of Quantities, the microprocessor based protection relays shall be rated at 230V/400V and operating voltage shall be in a range from 90V to 250V. The relays shall be housed in robust panel flush mounting case and shall be fully tropicalised and suitable to be used up to an ambient temperature of 50 oC and relative humidity of 95%.

Unless otherwise specified, the microprocessor based protection relays shall be of combined three phase over current and earth-fault protection with instantaneous, definite time and inverse time characteristics. Time / current characteristic of IDMT overcurrent and earth fault relays shall be of standard inverse curve (3/10).

The microprocessor based protection relays shall give numerical digital readout of set values, actual measured values and recorded values. The relays shall include a serial communication port for external connection to facilitate external reading, setting and recording of relay data and parameters by a personal computer (PC). PC connecting cable and parameter reading/setting /recording PC program shall be provided.

The microprocessor based protection relays shall be incorporated with built-in self-supervision system with auto-diagnosis. The self supervision system shall continuously monitor the relay microprocessor programs. If a permanent fault is detected, an alarm indication shall be given. A 230V/5A alarm contact for connection to external alarm shall be provided.

If current and voltage measurements are specified, the microprocessor based protection relays shall make available these measurements for local display. The measurements shall include phase currents, phaseto-phase voltages and phase-to neutral voltages.

The microprocessor based protection relays shall comply with relevant parts of IEC 60255 and shall also comply with relevant parts of IEC 61000 on electromagnetic compatibility.

13.0 MEASURING INSTRUMENT AND ACCESSORIES

Measuring instrument and accessories shall comply with the relevant IEC Standards. They shall meet the requirement as specified in the Drawings and/or Bill of Quantities.

13.1 MEASURING INSTRUMENT

Measuring instrument shall be of panel flush mounting type with square escutcheon plate finished matt black and pressed steel case. They shall be of industrial grade type adequately shielded against stray magnetic fields, conform to the measuring scales and arrangements as shown in the Drawings and calibrated for correct readings. They shall comply with MS 925 and relevant parts of IEC 60051. External zero adjustment shall be provided for ammeters and voltmeters.

Ammeters, unless otherwise specified, shall be of moving iron type having continuous overload capacity of 120% of rated value and full scale value accuracy of ±2%. They shall be provided with maximum demand indicator, if specified.

Voltmeters shall be of moving iron type having overload capacity of 200% of rated value and full scale value accuracy of ±1.5%.

Kilowatt-hour meter shall be of 6 numbers wheel cyclometer aluminium type with both the current and voltage coils on laminated cover fabricated from high quality silicon steel strip. They shall have overload capacity of 200% of rated value and accuracy of ±0.5% at the supply voltage and frequency characteristic.

Power factor meters shall be of balanced type using ferrodynamic, cross-coiled mechanism with measuring range from 0.5 lagging to 0.5 leading. Full scale value accuracy shall be ±1.5%.

Frequency meters shall be of reed type with frequency range from 45Hz. to 55Hz. and accuracy of ±5%. If specified in the Drawings and/or Bill of Quantities, the microprocessor based power meter shall be rated at 230V/400V and operating voltage shall be in a range from 90V to 265V.

The meters shall be housed in robust panel flush mounting case and shall be fully tropicalised and suitable to be used up to an ambient temperature of 50 ^{o}C and relative humidity of 95%. The meters shall give direct numerical digital readout of actual measured values and recorded values. The meters shall include one serial communication port for external connection to facilitate external reading and recording of meter data and parameters.

The measurements and their accuracy of the microprocessor-based meters shall be as per Table 6A: -

Parameters / measurements	Accuracy
Volts (V): line-line / line-neutral	0.5% of reading ± 2 digit
Currents (A): per phase	0.5% of reading ± 2 digit
Frequency (Hz)	0.1 Hz ± 1 digit
Power Factor: total	1% of reading ± 2 digit
Active Power (kW): total	1% of reading ± 2 digit
Reactive Power (kVAr): total	1% of reading ± 2 digit
Apparent Power (kVA): total	1% of reading ± 2 digit
Active Energy (kWh): total	1% of reading
Reactive Energy (kVArh): total	1% of reading
Maximum Demands (A, W, VA): total	1% of reading ± 2 digit

Table 6A: Accuracy of Microprocessor-based Meter

If harmonics content measurement is specified, individual and total harmonics distortion on the current and voltage up to 30th harmonic shall be measured with the accuracy of 1% of reading.

There shall be a custom display screen, which can be programmed to display customised specific parameter requirements.

All data shall be continuously and concurrently logged, recorded and stored in internal non-volatile memory. All time base logged-in data can be retrieved and downloaded to a personal computer (PC) using serial communication port. PC connecting cable and data retrieving PC program shall be provided.

The meters shall comply with IEC 60359 and IEC 60688. The meters shall also comply with relevant parts of MS IEC 61000 on electromagnetic compatibility.

14.0 CURRENT TRANSFORMER

Current transformers shall comply fully with MS 1202 and IEC 60044-1 and shall have short time rating not less than that of the switchboard in which they are incorporated. The secondary shall be rated for 5A. They shall be adequately rated in VA to carry the summation of all VA burdens of the connected loads but in any case, the rating shall not be less than 15VA. They shall be capable of withstanding, without damage, on open circuit secondary with full primary current.

They shall be constructed from high quality silicon steel core. They shall be installed inside the switchboard in such a way that it is easily accessible for maintenance purpose. Identification labels shall be fitted giving type, ratio, rating, output and serial numbers.

Unless otherwise specified, current transformers used for measuring and metering shall be of Class 1.0 accuracy and those used for protection shall be of Class 10P10 accuracy.

15.0 ISOLATING SWITCHGEAR

Isolating switches or switch-disconnector shall be of metalclad or high impact insulating material (e.g. polycarbonate) type. They shall fully comply to MS IEC 60947-1 and MS IEC 60947-3. The degree of protection shall be IP54 for indoor installation and IP65 for outdoor installation. They shall be able to operate continuously at full current rating without de-rating, capable of making and breaking currents under normal condition and when in open position, providing isolation from source of electrical energy for reasons of safety.

They shall be quick-make, quick-break type suitable for use on 230/400V, 50Hz. a.c. system and shall have padlocking facilities to secure against unauthorized operation. They shall be provided with removable top and bottom end plates or knockouts for cable entry. The enclosure, the isolating mechanism and all other accessories shall be from the same manufacturer.

The enclosure for metalclad type shall comprise of heavy gauge steel plates rust protected and finished grey stove enamel. Front access doors for metalclad type, which is detachable, shall be fitted with dust-excluding gasket and shall be interlocked to prevent opening when the switch is 'ON'. However this interlock shall be able to be defeated by competent person for maintenance purpose. It shall be provided with, if required, facilities for lock-on and lock-off the operating handle.

16.0 CONTACTORS

Contactor shall have the number of poles as specified in the Drawings and/or Bill of Quantities. They shall comply with IEC 60947-1 and 60947-4-1. They shall be fully tropicalised, suitable to be used up to an ambient temperature of 40 °C and suitable for use on 230/400 V, 50 Hz. a.c. supply system.

The contacts shall be of quick-make and quick-break type, dust-proof and rust protected. They shall be of utilization category as per Table 4A.

Current	Utilization Category	Typical Applications
AC	AC-1	Non Inductive or slightly inductive loads, resistance furnaces, heater
	AC-2	Slip-ring motors: switching off
	AC-3	Squirrel-cage motors: starting, switching off motors during running. Most typical industrial application
	AC-4	Squirrel-cage motors: starting, *plugging[1], *inching[2]
	AC-5a	Switching of electric discharge lamps
	AC-5b	Switching of incandescent lamps
	AC-6a	Switching of transformers
	AC-6b	Switching of capacitor banks
	AC-7a	Slightly inductive loads in household appliances: mixers, blenders
	AC-7b	Motor-loads for household applications: fans, central vacuum
	AC-8a	Hermetic refrigerant compressor motor control with manual resetting overload

	AC-8b	Hermetic refrigerant compressor motor control with automatic resetting overloads

*(1) Plugging - Stopping a motor rapidly by reversing the primary power connections.
*(2) Inching - Energizing a motor repeatedly for short periods to obtain small incremental movements.

Table 4A - Utilization Categories

The contactor shall have multiple auxiliary contacts, and unless otherwise specified shall be normally-open.

17.0 PROTECTION RELAYS

The protection device shall provide either instantaneous or inverse time lag characteristics in the overload range and instantaneous with or without time delay in the short circuit range as specified in the Drawings and/or Bill of Quantities. The protection device shall be of the type acceptable to the Supply Authority or Licensee and JKR. The protection relays shall be of panel flushmounting type. All relays shall comply with relevant parts of IEC 60255.

Overcurrent and earth fault protection shall be provided by externally connected current transformers.

Unless specified in the drawing and/or Bill Of Quantities, electromechanical overcurrent and earth fault relay shall be of Inverse Definite Minimum Time (IDMT) type.

a) For overcurrent relay of IDMT induction disc type, current settings shall be from 50% to 200% of rated current adjustable in seven equal steps and time multiplier settings from 0.1 to 1.0 adjustable continuously.

b) Earth fault relay of IDMT induction disc type shall have current settings from 10% to 40% of rated current adjustable in seven equal steps and time multiplier settings from 0.1 to 1.0 adjustable continuously.

Earth leakage relay (ELR) shall be of the type suitable for use on a 230/400V, 50Hz system and up to ambient temperature of 40 ^{o}C. ELR shall be provided with test button for simulation of a fault, earth leakage, LED indicator, a reset button, protection against nuisance tripping due to transient voltage and d.c. sensitive. Unless otherwise specified in the Drawings and/or Bill of Quantities, ELR shall be of adjustable current sensitivity and adjustable time delay type.

The selectivity range for current sensitivity shall be 0.03A to 10A and the time delay selectivity range of 0 second to 1 second. ELR shall be incorporated with matching balanced core current transformer and shunt trip coil for the circuit breaker to which it controls the tripping shall also be provided.

18.0 BUS DUCT SYSTEM

The Bus Duct System shall comply with BS EN 61439-6:2012. The bus duct shall be designed to accommodate an internal ground bus bolted to the inside of the casing and running throughout the entire system from source to load. The plug-in tap-off units shall incorporate suitably rated TPN MCCB's.

Bus bars shall be fabricated from high conductivity electrical grade copper and shall be capable of withstanding a fault level of not less than 80kA for 1-second duration. The bars shall be insulated with material that can withstand a temperature of 130°C and shall be silver-plated at plug-in points and joints. The insulation shall be seamless to prevent infiltration of water and moisture and also flame-retardant.

The bus duct joint shall be simple and tightened using a special ratchet wrench. Means to prevent improper tightening shall be built-in. The bus duct joint shall permit safe, practical testing of joints for tightness without de-energizing the bus duct. It shall be possible to remove any one length in a run without disturbing the two adjoining lengths.

Provision shall be included in each section to accommodate the differential expansion between adjacent lengths or between bars and casing. The temperature rise at any point in the bus duct shall not exceed 45° C rise above ambient temperature when operating at rated load current.

The neutral shall be full size and the equivalent cross-sectional area for the earth shall be half size.

Spring hangers shall support vertical duct runs.

Floor openings and wall openings shall be sealed with fire-resisting material to the appropriate degree of fire resistance to the approval of BOMBA.

19.0 MOTOR STARTER

A separate starter shall be provided for each motor for starting the motor against full load torque. The starter shall be mounted integrally on the control panel for automatic and manual operation. Motor starters shall be in accordance to BS EN 60947-4-1:2010+A1:2012and equipped with overload, single phasing, reverse phase and under-voltage protection.

All starters shall be of manual or automatic type complete with:

a) start/stop push buttons

b) manual/off/auto selector switch

c) run/stop/trip/locked out indicating light

d) ammeter/voltmeter/hour run meter

e) control and starting sequence of motor starters shall be as specified elsewhere.

Starters shall be suitable for minimum 15 operations per hour on full load, and up to 40 operations per hour on 60% full load. Starters shall be provided with temperature sensitive device, in order to isolate the motor, should an excessive temperature be detected by the embedded element.

The power factor of motors shall be not less than 0.85 lagging under any load condition. Suitably sized capacitors shall be supplied to raise the power factor of the motor to above 0.85. The power factor capacitors shall be suitable for use in damp tropical climate and in accordance to BS EN 60871-4:2014, BS EN 60831-1:2014and BS 6093:2006+A1:2013. The power factor

capacitors shall be rated for 525V. Sub-Contractor shall demonstrate and certify on site to prove that the power factor is above 0.85 when motors are running at any load. The Sub-Contractor shall coordinate with the suppliers/manufactures to ensure this requirement is satisfied and which the Sub-Contractor will be fully liable for any non-compliance of this minimum power factor requirements.

20.0 MOTOR CABLE

Sizing of motor cables shall conform to CME and IEE requirements and shall be of adequate size to allow for motor voltage conversion without replacing the cable. The motor cable shall be able to withstand the aggressive nature of the media. The cable entry water seal design shall be such that it shall be watertight without the use of epoxy, silicone or other secondary sealants. The motor cable shall be complete with oil and corrosion resistant chloroprene rubber sheathing.

21.0 EQUIPMENT FOR SCADA INTERFACE

Volt-free contacts provided shall comprise a pair of contacts operated directly by the equipment but electrically separated such that no potential derived from the equipment appears at the contacts. Volt-free contacts shall be used to complete external alarm or indication circuits with the supplies for these circuits being obtained from an external source. For the equipment to be controlled by the SCADA, the SCADA will transmit a 24V AC voltage to the interface termination block. There shall be one interface for control open and one for control close operations. The Sub-Contractor shall provide appropriate equipment to sense and latch the voltage for performing the open/close control function.

Volt-free contacts shall be readily convertible from NO to NC and vice versa by simple field adjustment. Contacts shall be rated to adequately make and break and carry continuously not less than 5A at 230V AC or 2A at 110V DC.

Volt-free contacts for sequence of event (SOE) alarms shall firmly close and seat in position once activated. The contacts shall not bounce or vibrate due to internal or external causes. Otherwise, other means to prevent repetitions signals due to bouncing of relay contacts shall be provided.

22.0 WIRING DIAGRAMS

LV Switchboards shall be provided with a wiring diagram suitably treated to prevent deterioration from dirt or age. The diagrams shall be drawn as if viewed from the point of access to the enclosure, and shall be securely fastened to the inside of the access door of that compartment.

23.0 REMOTE MONITORING

Critical status and alarms for each LV Switchboards shall be sent to SCADA for remote monitoring via volt-free contacts rated at 24V DC, 1A provided in the LV Switchboards: Individual ACB open/ close status, Common alarm for ACBs trip on fault/ lock out, Common alarm for any local/remote or local/ auto selector switch in local mode, 110V DC power supply failure, Emergency push button (EPB) operated, and LV Switchboards under voltage alarm.

24.0 FINISHES

a. All exposed metal surfaces, both internal and external, shall be thoroughly cleaned of all dust, oil, grease, dirt, scale, rust or other contaminants and shall be epoxy powder coated immediately at the manufacturer's factory.

b. The epoxy powder coating shall be not less than 75 micron thick and with colour in accordance with BS 381C or BS 4800.

c. All surfaces of the LVSBs shall have any damage to the finished coating made good on completion of installation and shall then be painted to its original finished colour.

d. Painting procedure, paint samples and manufacturers shall be approved prior to commencement of painting.

e. Touch-up proposals to make good any areas/ surfaces that have been damaged on Site or in transit shall be submitted for Approval.

25.0 NAMEPLATES AND LABELS

a. Nameplates

i. Each LV Switchboard shall have permanently attached to it in a conspicuous position a label or labels upon which shall be engraved or stamped with the manufacturer's name, type and serial number, date of manufacture, designation of each LV Switchboard, details of the loading and duty at which the item of the LV Switchboard has been designed to operate. Such labels shall be of non-hygroscopic material.

b. Labels

i. Labels shall be provided for every panel to describe the duty of or otherwise identify every instrument, relay or item of control equipment mounted externally and internally.

ii. The designation on these labels shall be clear and shall, where applicable, incorporate the device number along with concise descriptive wording in English or Bahasa Malaysia.

iii. Externally fitted panel labels shall be of perspex or other Approved transparent plastic with letters and numbers rear engraved and filled with black.

iv. Internally fitted panel labels shall be finished in white with engraved letters and numbers filled with black, laminated material such as Traffolyte or rear engraved and filled plastic may be used. Embossed materials and techniques will not be accepted.

v. Labels shall be provided in conformity with the above requirements or by other Approved means wherever necessary to designate panels or panel sections, to describe or identify circuits or circuit components, to provide warnings or

reminders of dangerous or potentially dangerous circumstances and wherever called for elsewhere in this Specification.

vi. Safety labels “DANGER, 400V” in English or Bahasa Malaysia shall be provided on the LV Switchboards. The safety labels shall have graphic symbols and wording in red on a white background. The design of all such signs shall be submitted for Approval. Similar labels shall be provided for other panels at different voltages.

vii. Labels shall not be less than 45mm high. Lettering shall be of not less than 10mm high. All labels shall be securely fixed to the panels by bolts and nuts.

viii. Details of proposed inscription, including the English and Bahasa Malaysia wordings, and samples of the labels shall be submitted for Approval before any labels are manufactured.

26.0 OTHER PROVISIONS

The LV Switchboards shall be provided with all necessary cable lugs etc., fixed in positions on mounting plates and straps, to suit the types and directions of entry of the cables.

Cable conductors for all circuits within the LV Switchboards shall be arranged in a tidy manner and mechanically secured at regular intervals such that any movement occurring to the conductors, either under normal operation conditions (e.g. thermal expansion and vibration) or due to short circuit in any one of the circuits, shall not cause any damage or short circuit to any healthy bare live parts in the LV Switchboards.
Each LV Switchboards shall be supplied complete with all operating handles jigs, etc. required for the normal charging, closing, opening, racking in and out operations of all circuit breakers of the LV Switchboards and shall be properly fixed in a neat manner on a board with brass hooks inside the switch room/ plant room where the LV Switchboards is installed.

Each LV Switchboards shall be provided with two rubber mats of ribbed surface, complying with IEC 61111:2009, laid in front of and at the rear of the switchboard. The rubber mats shall be continuous sheets of minimum thickness of 10mm, each of same length as the switchboard and minimum width of not less than 1000mm or the width of the space between the front or back of the switchboard to the adjacent wall.

Hydraulic operated handling truck suitable for handling all sizes of air circuit breakers for the LV Switchboards shall be provided as required.

END OF SECTION

EMFP - MAIN FEEDER PILLAR AND FEEDER PILLAR

CONTENTS

1.0 MAIN FEEDER PILLAR AND FEEDER PILLAR

1.1 General

The Main Feeder Pillars and Feeder Pillars shall be supplied completely assembled with control gear and all internal electrical and mechanical interconnections and structural parts for voltages up to and including 1000 volts A.C. It shall comply with and be tested to the requirements of IEC 61439 – 1 & 2 and IEC 61439 - 5.

The Electrical Contractor shall submit design drawings showing the plan, elevations, sections, layout and construction details of the feeder-pillar for the approval of the CR prior to fabrication. The plinth, foundation work, ducting, etc. shall be included in the design drawing.

1.2 Housing

Main Feeder Pillars and Feeder Pillars shall be manufactured from sheet steel/stainless steel 316 of minimum thickness 12 SWG (frame) and 14 SWG (plate) and the structure shall be suitably reinforced with angle or channel irons where appropriate as specified in the Drawings. In general, they shall comply with IP 56 of IEC 60529:2013.

The main feeder pillars and feeder pillar cabinets shall have an angle iron base frame in which holes have been prepared to suit foundation bolts for fastening the feeder pillar on to a concrete foundation structure. Doors for the feeder pillar shall be locked with either wedge type lock protected by screw plugs or some other form of lock approved by the CR. The doors shall be hinged internally to prevent unauthorized access. The pillar shall be self-ventilated and weatherproof. A non-perishable resilient gasket shall be provided size and enclosed in a clear plastic envelope shall be enclosed in a holder which shall be provided on the inside of the front door panel.

An approved sign shall be stencilled on the front and rear of the pillar using red paint to indicate that the pillar houses electrical equipment. The main feeder pillar and feeder pillar cabinet shall be sheet steel/stainless steel 316 as specified in the Drawing.

1.3 Busbars

Busbars shall be of high-conductivity tinned copper bars of sufficient cross-sectional areas and rupturing capacities to cater for the voltage and current ratings as indicated in the schematic Drawings. Busbar marking, and clearance between busbars and the framework of the feeder pillar shall be in accordance with BS 158.

1.4 Earthing Terminal And Cable Entry

An earthing terminal in the form of bolt of minimum dimensions 6mm diameter and 20mm long shall be welded onto the base frame for connection of the earthing copper strip. Sufficient earth electrodes shall be planted so that the requirements for earth loop impedance specified by current IET Wiring Regulations for Electrical Installations (18th Edition) are met. The feeder pillar shall be provided with a gland plate equipped with sufficient holes so that XLPE/SWA/PVC cables of sizes such as 25mm^2/4C or 16mm^2/4C would be anchored by means of cable glands.

1.5 Foundation

Foundation for feeder pillars shall be of reinforced concrete Class 25/20 as shown on the Drawings.

After completion of the cabling, the void in the feeder pillar base shall be filled to 25 mm below the door with clean sand.

The site for the foundation of the feeder-pillar shall be excavated and filled where required, compacted and levelled before the reinforced concrete base is constructed to a minimum of 300 mm. (or otherwise specified) above the finished ground level and 900 mm below the finished ground level as specified in the drawings. Cable entry ducts shall also be provided as specified in the Drawings.

1.6 Earthing

The earthing system for the feeder-pillar shall comply with the requirements of MS IEC 60364, BS 7671:2018 (known as the IET Wiring Regulations), JKR, Suruhanjaya Tenaga and in accordance with the Drawings. Each main feeder pillar and feeder-pillar shall be effectively earthed by using 16mm. diameter copper jacketed steel core rods, 25mm x 3mm copper tape and heavy duty inspection chamber with removable cover, etc.

1.7 Contactors

The contactor supplied shall comply to IEC 60947-4-1 :2019 with uninterrupted ratings mechanical duty class 2 and utilisation category of minimum AC3. The contactor coils shall be fully tropicalized and wound for continuous operation for 230/400 V, 50 Hz supply. The contacts of the contactor shall be rated for the breaking capacity on the connected load.

1.8 By-pass Switch and Selector Switch

A single and three phase by-pass switch as applicable shall be connected in parallel with the contactor for use in the event of the failure of the contactor. This by-pass switch shall be manufactured to BS EN 60947-3:2021 and shall be capable of breaking the load connected without undue wear or damage. A four position selector switch shall be provided to select the mode of operation and shall be appropriately labelled.

1.9 Moulded Case Circuit Breakers (MCCBs)

a. All $MCCB_s$ shall be designed for horizontal or upright mounting without any adverse effect on electrical performance.
b. Operating mechanisms shall be of the quick make, quick break type with the speed of operation independent of the operator, and mechanically trip free from the operating handle so as to prevent the contact from being held closed against short circuit and overload conditions. The operating mechanism shall be constructed to operate all poles in a multi-pole breaker simultaneously during opening, closing and tripped conditions.
c. The breakers shall be operated by a toggle which shall clearly indicate the three fundamental position ON, OFF and TRIPPED. A manual trip button shall be provided

at the exterior to trip the circuit breaker mechanically. It shall also be used to check the trip alarm switch operation.

d. The breaking and extinction of the electrical arc shall be achieved by means of non-welding contacts made of silver alloy and an arc chute surrounding these contact.

e. MCCBs shall be specially surface-treated against corrosion without need for corrosion-proof boxes or enclosures.

f. Each pole of the MCCBs shall be provided with bi-metallic thermal element for inverse time delays protection and magnetic element for short circuit protection. The thermal release shall be of the adjustable type (from 70% to 100% of rated current) and equipped with sealing facilities. The magnetic element shall have instantaneous tripping characteristic.

1.10 Miniature Circuit Breakers.

Unless otherwise indicated in the Drawings and/or Bill of Quantities, miniature circuit breakers (MCBs) shall have breaking capacity not less than 10 kA (rms) and of B-type with Class 3 energy limiting characteristics. They shall comply with IEC 60898-1 & IEC 60947-2, fully tropicalized and suitable for use on a 240/415 V, 50Hz A.C. system and in an ambient temperature of 40ºC. They shall be quick-make, quick-break and trip free complete with de-ion arc interrupters. The tripping elements shall be of thermal magnetic type with inverse time delay overcurrent and instantaneous short circuit characteristics. The response to overload shall be independent of variations on ambient temperature.

They shall be manually operated by means of toggle type handle having visual indication of whether the breaker is opened, closed or tripped. Multiple breakers shall be provided with a common trip mechanism for simultaneous operation of all the poles.

1.11 Termination

All cables terminated into the various components including incoming and outgoing cables must be terminated through compression glands and heat shrinkable sleeves.

1.12 Factory Test

The Electrical Contractor shall make arrangements for a joint inspection and to witness the electrical tests at the factory prior to transportation to the site of the main feeder pillars and feeder pillars. All costs incurred shall be deemed to be included in the tender price. Test certificates shall be issued upon completion of all tests.

END OF SECTION

ESPS - SURGE PROTECTION SYSTEMS

CONTENTS

ESPS - SURGE PROTECTION SYSTEM

1.0 GENERAL

Generally, a comprehensive surge protection system shall be provided. The proposed system shall be suitable for local lightning environment and consist of different protection stages appropriate to their respective usage locations. Data communication surge suppressors shall also be provided by the Electrical Contractor and shall be suitable for use in accordance with the equipment specifications. The surge protection shall be installed at various locations of the low voltage equipment and the Electrical Contractor shall indicate in the design drawings. The surge protection system shall be of the latest product and technology available. The surge protection system provided at the main switchboard, sub-switchboard and distribution board shall be supplied by the same manufacturer to ensure product compatibility.

The Lightning and Surge Protection System using SPD shall be suitable for TT system (3+1) / TN-S installation, 230/400Vac unless otherwise specified.

The SPD Protection mode shall be suitable for Connection Type 2 (CT2) according to MS IEC 61643-12 as follows:

a) CLASS I/Type 1 consist of 4modules (3+1) - 3LINE(S) to NEUTRAL(N) and 1NEUTRAL to PROTECTIVE EARTH (PE) - must be fully encapsulate, pre-triggered spark-gap for ALL modules.
b) CLASS II/Type 2 consist of 4modules (3+1) - 3LINE(S) to NEUTRAL and 1NEUTRAL to PE. The N-PE module must be spark-gap
c) CLASS III/Type 3 must offer comprehensive protection in common and differential mode - 3LINE(S) to NEUTRAL, 3LINES to PE and 1 NEUTRAL to PE. The PE module must be spark-gap

The SPD install at all level must had Voltage Protection Level (Up) less than 1.5kV for equipment category 1 to MS IEC 60364-4-44. Up declare at 3kA is only acceptable for Class III/Type 3.

a) CLASS I/Type 1 - Iimp @ 10/350us less than 1.5kV at the Main SwitchBoard
b) CLASS II/Type 2 - In @ 8/20US less than 1.25kV at the Sub Main SwitchBoard/Main Distribution Board
c) CLASS III/Type 3 install at D/B or near equipment's shall offer the lowest voltage protection (Up) level less than 1kV
d) Surge Protection for Information Technology and Sensitive equipment's shall be properly proposed to effectively counter the problems using Class I, II & III to MS IEC61643-21

ALL SPDs must be able to carry the prospective Short Circuit current at point of installation until it is interrupted either by the SPD itself internally or by the external overcurrent protection devices as per MS IEC 61643-12 Annex "A" - 3.7 Rating under - I imp, I max, I n & I total - of the SPD cannot be applied in this Isccr clause.

a) CLASS I/Type 1 - Iimp @ 10/350us at the MSB - minimum 50kA rms "short circuit current withstand" (Isccr) with recommended Type tested protection devices
b) CLASS II/Type 2 - In @ 8/20US at the Sub MSB/Main D/B - minimum 25kA rms "short circuit current withstand" (Isccr) with recommended Type tested protection devices

c) CLASS III/Type 3 install at D/B or near equipments - 6kA (Isccr)

The Protection device above shall NOT limit the discharge capability of the SPD performances as per MS IEC 61643-12 - Annex "N". All SPDs discharge capablility shall be of Iimp (Class I), In (Class II & Class III). **Imax cannot be considered due to the higher Up which will be more than the impulse withstand voltage of the equipment to be protected as the SPD will survive such stress but NOT the equipment.**

Mechanical indicator shall show the workable status in ALL SPD module(s), Green - OK ; RED - Fail/Change

The cross section of the connecting cables shall be greater if the maximum Prospective Short circuit Current requires it. The conductor length must be less than 0.5M from SPD to Earth conductor

The operating temperature of ALL SPD must be - 40° C to + 80° C for connection in parallel without physical damages during high discharge function.

Energy coordination with other arrestors (SPD) from CLASS 1/Type 1) with CLASS 2/Type 2 and CLASS 3/Type 3 shall be under one manufacturer product family. Support of single line drawing together with energy coordination of SPDs must be submitted as per MS IEC 61643-12 - Annex "J" - 2.2

Electronic impulse counter shall be provided as an option to register discharge current flowing through the SPDs.

2.0 STANDARDS

The specifications of the surge suppressors shall comply with the guidelines as outlined in the International Standard IEC-61643-11, IEC-61643-12 , IEC -61643-21, IEC-61643-22. and IEC 60364-4-44: + AMD2 :2018

Standards	Document Titles
MS IEC 61643-11 : 2012 +A11: 2018	LV SPD Pt. 11. SPD connected to LV power systems- Performance Requirements & Test Methods
MS IEC 61643-12 :2020	LV SPD – Pt. 12. SPD connected to LV power distribution system- Selection and Applicable Principles.
IEC-61643-21: 2001 +AMD1:2008 +AMD2 : 2013	Low voltage surge protective devices - Part 21: Surge protective devices connected to telecommunications and signaling networks - Performance requirements and testing methods
IEC 61643-22: 2015	Low voltage surge protective devices - Part 22: Surge protective devices connected to telecommunications and signaling networks - Selection and Applicable Principles.

IEC 60364-4-44: 07 + AMD1:2015 CSV + AMD2: 2018 CSV © IEC 2018	Electrical Installations- Pt. 4-44. Protection for Safety- Protection against voltage disturbances and electromagnetic disturbances.
MS IEC 62305-3:2011	Protection against Lightning- Part 3. Physical damage to Structures.
MS IEC 62305-4:2011	Electrical & Electronic System – Part 4. Hazards within structures
MS IEC 60364-5-53:2019 + AMD1 :2020 CSV	LV Electrical Installation. Selection & Erection of Electrical equipment – Devices for protection, safety, isolation, switching, control & monitoring

ALL Lightning Current and Surge Protection devices must be Type Tested by 3rd Party (KEMA, VDE etc.) with Certificates and also tested to "VIBRATION & SHOCK-TESTED" in accordance to EN 60068-2.

Summary of Testing to MS IEC61643-11:2012 shall include as follows:

a) Residue voltage
b) Spark-over voltage
c) Operating duty test
d) Short Circuit Test
e) Temporary overvoltage
f) Total discharge current
g) Voltage regulation & Temperature rise test
h) Fault condition trigger
i) Insulating material test and Glow wire test
j) Terminal and Electrical connection

3.0 TECHNICAL AND INSTALLATION REQUIREMENTS

3.1 Surge suppressor installed at Main Switchboard

The power surge suppressor installed at the Main Switchboard shall be suitable for use in an area of frequent thunderstorms requiring maximum protection in order to control large surge transients that may be detrimental to the building's LV power distribution system.

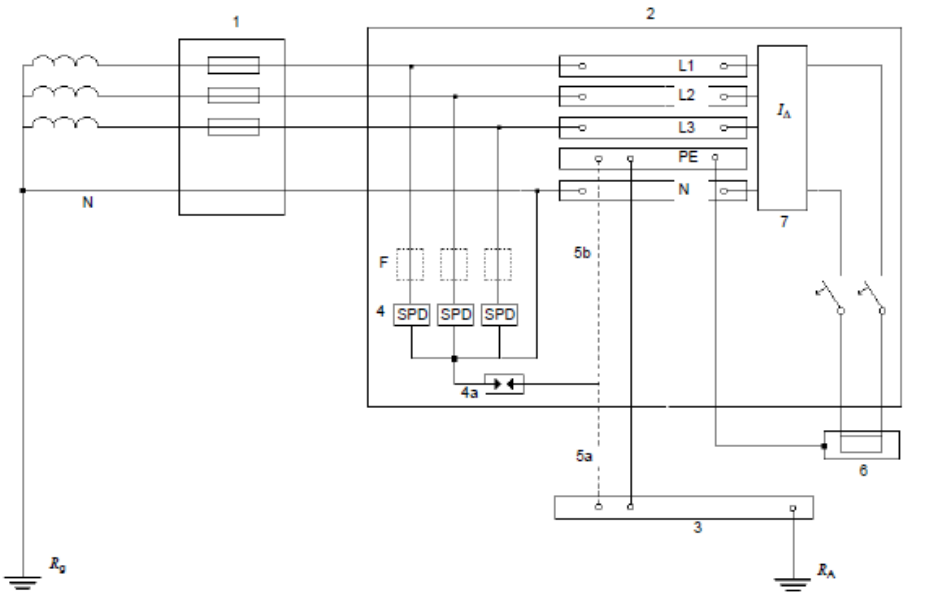
The requirements for power surge suppressor at the main switchboard are as follows:-

1. The power surge suppressor shall be of one-port type with specification that is able to provide long term protection with high performance and reliability. It shall be heavy duty triggered spark gap surge suppressors that are compliant to IEC 61643-11 Class I requirements with lightning impulse current (10/350us *Iimp*) discharge capability for L-N of 25kA and N-PE of 100kA in the configuration of IEC 61643-12, Annex K Figure K.3 and MS 1979:2007, COP 59

1.1 Code of Practice 59 (COP), Installation of SPD

To protect against lightning surges or overvoltage surges, it is recommended to install a surge protective device (SPD) near the origin of the installation. The SPD is recommended to be installed before the RCD (on the supply side).

Installation Guidelines per IEC 61643-12, Annex K Figure K.3 for TT or TN-S electrical system MS **IEC 61643-12:2020**



Key

1	Origin of the installation
2	Distribution board
3	Main earthing terminal or bar
4	Surge protective devices
4a	Surge protective device in accordance with IEC 60364-5-53 (2.3.2) or spark gap
5	Earthing connection of surge protective devices, either location 5a or 5b
6	Equipment to be protected
7	Residual current protective device (RCD)
F	Protective device indicated by the manufacturer of the SPD (for example, fuse, circuit-breaker, RCD)
R_A	Earthing electrode (earthing resistance) of the installation
R_g	Earthing electrode (earthing resistance) of the supply system

Figure K.3 – Installation of surge protective devices in TT-systems (SPD upstream of the RCD)

2. In order to minimize let-through voltage reaching downstream systems even at high level of lightning current, in addition to high lighting current discharge capability above, the surge suppressor shall be able to achieve protection level (Up) of 1.5kV (L-N) and 1.5kV (N-E) or lower tested according to relevant IEC 61643-11& IEC 60364-4-44, Table 443.2

Table 443.2 – Required rated impulse voltage of equipment U_W

Nominal voltage of the installation [a] V	Voltage line to neutral derived from nominal voltages a.c. or d.c. up to and including V	Required rated impulse withstand voltage of equipment [c] kV			
		Overvoltage category IV (equipment with very high rated impulse voltage) IV	Overvoltage category III (equipment with high rated impulse voltage)	Overvoltage category II (equipment with normal rated impulse voltage)	Overvoltage category I (equipment with reduced rated impulse voltage)
		For example, energy meter, telecontrol systems	For example, distribution boards, switches socket-outlets	For example, distribution domestic appliances, tools	For example, sensitive electronic equipment
120/208	150	4	2,5	1,5	0,8
230/400[b,d] 277/480[b]	300	6	4	2,5	1,5
400/690	600	8	6	4	2,5
1 000	1 000	12	8	6	4
1 500 d.c.	1 500 d.c.			8	6

[a] According to IEC 60038:2009.

[b] In Canada and USA, for voltages to earth higher than 300 V, the rated impulse voltage corresponding to the next highest voltage in this column applies.

[c] This rated impulse voltage is applied between live conductors and PE.

[d] For IT systems operations at 220-240 V, the 230/400 row shall be used, due to the voltage to earth at the earth fault on one line.

3. The surge suppressor shall be types that are providing protection for each phase-to-neutral (L-N) and neutral-to-earth (N-E) conductors for either single or three phase supply system.

4. The nominal voltage of the surge suppressors shall be 230/400V to comply with local voltage supply requirement. There should be no power harmonics caused by the surge suppressor and the idle power of the surge suppressor shall be less than 1W for any single module.

5. All SPD shall have datasheets with accompanying 3rd Party Type-Test Certificate by KEMA or DEKRA
   - . Only Voltage Protection Level, U_p, is important for equipment protection.

6. The maximum continuous operating voltage (MCOV) of the power surge suppressor must be at least 275 volts for MOV type SPDs and 255 Volts for Spark Gap Devices
   a) According to Annex K Figure K.3 of IEC 61643-12, N-PE pole must be Spark-Gap, therefore it is good to state spark-gap voltage range here.
   b) MOV have leakage currents as it is a semi-conductor device, therefore its MCOV must be higher to avoid high leakage current. Spark-Gaps on the other

hand are open-circuit under normal conditions, therefore can be much closer to line voltage for best performance in terms of Voltage Protection Level, Up.

7. The power surge suppressor shall be able to coordinate with downstream sub-switchboard/distribution board surge suppressor without dependent on cable separation requirement in handling surge so as to minimize stress on the downstream surge suppressor and also switchgears.

8. Remote dry contact (NO/NC) and status indicator either integrated or as an additional add-on module shall be provided in order to provide surge suppressor status feedback. The surge suppressor shall be of type DIN rail mountable with individual module replaceable in the event that it needs replacement.

9. The power surge suppressor shall be type that do not experience thermal dissipation problem and the enclosure material shall be of metal or have the highest inflammability class rating of V-0 in accordance with UL94 standard.

10. To maintain long term consistent performance, the surge suppressor shall not employ friction-based connection method in its cabling to the power system. All connection shall be of heavy bolt-type capable of accommodating cable size up to $50mm^2$

11. The working temperature of the device shall be -40C to +80C.

12. The device shall be protected by overcurrent protection device to Table N.1. of Annex N in IEC 61643-12. Manufacturer must show calculation using formulas provided in Annex P if the listed kA rating of SPD, I_{imp} or I_{max}, is not stated in Table N.1. Gg Fuse Switch is preferred as stated by Annex N. MCCB or Fuse size inconsistent with Table N.1 will be rejected. Alternatively, Manufacturer can be furnished with 3rd-Party Type-Test Reports for proof of injected Iimp or In/Imax that resulted in the recommended fuse rating.

4.0 SURGE PROTECTION DEVICES

4.1 Surge suppressor installed at Sub-Switchboard/Distribution Board

The power surge suppressor installed at the Sub-Switchboard/Distribution Board shall be suitable against transient overvoltages, generated by the secondary effect of lightning as well as by inductive coupling or electrical switching to control medium large surge transients that may be detrimental to the building's LV power distribution system.
The requirements for power surge suppressor at the sub- switchboard/distribution board are as follows:-

- The power surge suppressor shall have In of 20kA (8/20us) and I_{max} of 40kA (8/20us) between L-N and N-PE as a complete device in accordance to IEC 61643-11 Class II and configuration to Annex K Figure K.3 in IEC 61643-12 for TT or TN-S electrical system

- The power surge suppressor shall have protection level (Up) tested according to IEC 61643-11 Class II not exceeding 1.5kV when tested at nominal discharge current (In).

- All SPD shall have datasheets with accompanying 3rd Party Type-Test Certificate by KEMA or DEKRA .

- All SPD can achieve Class/Type 2 SPD type test requirement for SSB to IEC 61643-11, can be qualified to use. Response time is not a requirement under the standards.

- Only Voltage Protection Level, Up, is important for equipment protection.

The maximum continuous operating voltage (MCOV) of the power surge suppressor must be at least 260 volts for MOV type SPDs and 255 Volts for Spark Gap Devices.

a) According to Annex K Figure K.3 of IEC 61643-12, N-PE pole must be Spark-Gap, therefore it is good to state spark-gap voltage range here.
b) MOV have leakage currents as it is a semi-conductor device, therefore its MCOV must be higher to avoid high leakage current. Spark-Gaps on the other hand are open-circuit under normal conditions, therefore can be much closer to line voltage for best performance in terms of Voltage Protection Level, Up.

- The power surge suppressor shall have Line-Neutral (L-N) and Neutral-Earth (N-E) protections based on Annex K Figure K.3 of IEC 61643-12.

- The power surge suppressor shall be furnished with status indicator (one per phase) and dry contact for remote alert status.

- Each surge suppressor component must be thermally fused, to disconnect should an abnormal power condition leads to excessive MOV heating.

- The working temperature of the device shall be -40 C to +80C.

a) The device shall be protected by overcurrent protection device to Table N.1. of Annex N in IEC 61643-12. Manufacturer must show calculation using formulas provided in Annex N if the listed kA rating of SPD, Iimp or Imax, is not stated in Table N.1. Gg Fuse Switch is preferred as stated by Annex N. MCCB or Fuse size inconsistent with Table N.1 will be rejected. Alternatively, Manufacturer can be furnished with 3rd-Party Type-Test Reports for proof of injected Iimp or In/Imax that resulted in the recommended fuse rating.

Table N.1 – Examples of ratio between single shot withstand and full preconditioning/operating duty test

Withstand capabilities of gG fuse-links towards operating and additional duty tests					
Rated currentof fuse link (A)	**Minimum prearcing I^2t(Table 113, IEC 60269-2))**	**Evaluated minimum Adiabatic $I^2t(A^2s)$**	**Safety coefficient (on the valueof current)**	**Maximum I_n (kA) (8/20 µsec)**	**Maximum I_{imp}(kA) (10/350 µsec)**
8	40	24	0,85	1,2	0,3
10	68	41		1,5	0,3
12	130	78		2,1	0,5
16	291	175		3,1	0,7
20	640	384		4,6	1,0
25	1 210	726		6,4	1,4
32	2 500	1 750		9,9	2,2
40	4 000	2 800		12,5	2,8
50	5 750	4 025		15	3,4
63	9 000	6 300		19	4,2
80	13 700	10 960		25	5,6
100	21 200	19 080		33	7,3
125	36 000	32 400		42	9,6
160	64 000	57 600		57	13
200	104 000	93 600		72	16
224	139 000	125 100		83	19
250	185 000	166 500		96	22
315	302 000	271 800		123	28
400	557 000	445 600		157	35
500	900 000	720 000		200	45
630	1 600 000	1 280 000		267	60

Explanations to the data provided in Table N.1:

Column 2 — These minimum pre-arcing I^2t values are extracted from IEC 60269-2, table 113. They refer to a pre-arcing time of 4 ms and have originally been established as reference value by SC32B.

Column 3 — These values are calculated based on material constants and the shape of thefuse strip. They refer to a melting time of approximately 3 ms and are confirmed by experience.

Column 4 — This is a safety coefficient to take into account different fuse dimensions.

Columns 5+6	These values are based on calculation from column 3 and confirmed by experimental data from operating duty tests.

The values contained in Table N.1 should be applicable for all kinds of gG fuse links, irrespective of their dimensions, but are not applicable to other fuse characteristics.

Other fuse characteristics need to be checked separately by applying the complete operating duty test procedure as described in IEC 61643-11.

NOTE : Most of the experimental data used as a basis for Table N.1 and the corresponding calculations for 10/350 impulse currents are based on NH fuses. However, some tests performed on a few cylindrical fuses have confirmed the above mentioned withstand capabilities for that fuse dimension.

4.2 Data/Signal Line Transient Surge Suppressor

The Data/Signal line transient surge suppressor shall be installed on all signal/data lines entering or leaving the building, in order to protect equipment connected to the line, against transient overvoltage. Where data/signal lines linking equipments in separate building, the transient protection devices shall be installed at both ends of the line in order to protect both pieces of equipment. These requirements cover the primary protectors for use in single or multiple pair-type line circuits.

The requirements for the Data/Signal lines transient surge suppressor are as follow: -

- The SPDs shall have surge rating in accordance to IEC 61643-22 requirements for the zone stated below:
  a)LPZ 0→1, Type 1, D1, Protection P1. SPD capable of withstanding I_{imp} of 2.5kA (10/350us) per line. While ensuring voltage protection level of P1, L-L' not more than 120V over the operating voltage of the ELV cable.
  b)LPZ 1→2 Type 2, C2, Protection P1. SPD capable of withstanding In of 10kA (8/20us) per line. While ensuring voltage protection of P1, Up of L-L' lower than 120 V.
- The line-to-line protection level (Up) of the transient surge suppressor shall not exceed 500V requirement as stated in IEC 61643-22.
- All transient surge suppressor shall be selected for the particular data frequency and signal level characteristics of the application.
- The transient surge suppressors housing shall be made of durable, lightweight, corrosion resistant, high impact plastic of non-flammable material.

4.1 Telecommunication lines installed at MDF Frame/Panel

The telecommunication surge suppressor shall provide maximum protection for the PABX and other telephone system against large transient overvoltage generated by the lightning discharge current from nearby telephone overhead lines and other voltage surges.

The telecommunication surge suppressor shall be installed at Telephone Main Distribution Frame/Panel (MDF).

- The SPDs shall have surge rating in accordance to IEC 61643-22 requirements for the zone stated below:
  a) LPZ 0→1, Type 1, D1, Protection P1. SPD capable of withstanding I_{imp} of 2.5kA (10/350us) per
  b) line. While ensuring voltage protection level of P1, L-L' not more than 120V over the operating voltage of the ELV cable.
  c) LPZ 1→2 Type 2, C2, Protection P1. SPD capable of withstanding In of 10kA (8/20us) per line. While ensuring voltage protection of P1, Up of L-L' lower than 120 V.
  d) Must be 10 pair plug in on KRONE type SPD with Type 1+3. Type 1 with D1 spec using Gas Tube and Type 3 with C1 spec using MOV or SAD diodes. Up less than 500V

5.0 MAIN SWITCHBOARD / MCC AND OUTDOOR PANEL

CLASS I & II / TYPE 1&2 - SPDs selected shall discharge maximum 100kA (N-PE,10/350us) to Lightning Protection Level I (200kA).

Unless specified, Lightning Protection Level II & III/IV - the SPD shall be proposed accordingly.

SPD using multiple series of MOVs connected in parallel shall have a reducing scaling factor of 20 due to the stress impose by a 10/350us test on a 8/20us test. Test report at 10/350us need to verify the actual discharge current test.

The SPD protection modules must be pre-ignited SPARK-GAP design, fully encapsulated, self-extinguishing (non-exhausting) with plug-in modules interlock in position at the prewired base, neither vibration nor strong electromagnetic forces during discharge can loosen the connection.

The Class I & II SPD must be capable to handling Energy Coordination to other SPD downstream as well as to end equipment.

The SPD shall be install at the supply (LINE) side of the RCD/ELR and protection against indirect contact shall remain effective in the event the SPD failed; in accordance to MS IEC 60364-5-53:2003.

NO Leakage Current from the SPD shall not cause unnecessary interruption of the RCD. Specification as follows:

a)	Lightning Impulse Current (10/350us)	L-N per module	I imp	25kA /module as specified
b)	Lightning Impulse Current (10/350us)	N-PE	I imp	100kA
c)	Max continuous operating voltage		Uc	255Vac
d)	Voltage Protection Level at Iimp	L-N	U p	< 1.50kV
e)	Voltage Protection Level at Iimp	N-PE	U p	< 1.50kV
f)	Prospective Short Circuit Current	Parallel wiring	Isccr	min 50kA rms with 315A fuses

g)	Follow Current extinguishing capability	L-N	I fi	50K A rms
h)	Operating Temperature		Tu	- 40° C to + 80° C
i)	Temporary Overvoltage -TOV	L-N	U t	440V / 5sec
j)	Temporary Overvoltage -TOV	N-PE	U t	1200V / 200ms

CLASS 1 (TYPE1) and CLASS I&II (TYPE 1&2) SPARK GAP SPDs must provide a 5years product warranty.

6.0 SUB MAIN BOARD / DISTRIBUTION BOARD

CLASS II/Type 2 - SPDs selected shall have minimum discharge current In - 20kA (8/20us) to discharge the indirect lightning strike and switching current wave 8/20us test without physical damages or overheating the MOV. It must be properly coordinated with the Class I SPD above.

SPD nominal discharge current In, shall be the only normative ratings.

The SPD protection modules for L-N modules shall feature SINGLE heavy duty zinc oxide varistor in combination with safety protection featuring dual "THERMAL DYNAMIC CONTROL" monitoring device, preventing fire during failure. The N-PE module must be of high discharge capacity "SPARK-GAP" technology to prevent unnecessary tripping of RCD/ELR. The plug-in modules interlock in position at the prewired base and neither vibration nor strong electromagnetic forces during discharge can loosen the connection. The SPD install shall coordinate with the RCD/ELR and protection against indirect contact shall remain effective in the event the SPD failed; in accordance to MS IEC 60364-5-53:2003 if install after the RCD/ELR.

The plug-in modules interlock in position at the prewired base and neither vibration nor strong electromagnetic forces during discharge can loosen the connection.

NO Leakage Current from the SPD shall not cause unnecessary interruption of the RCD/ELR.

Specification as follows:

a)	Nominal Discharge Current (8/20us)	L-N per module	I n	20kA
b)	Lightning Impulse Current (10/350us)	N-PE	I imp	12kA
c)	Follow Current extinguishing capability	N-PE	I fi	100A rms
d)	Max continuous operating voltage		Uc	275Vac
e)	Voltage Protection Level at In	L-N/E	U p	<1.50KV
f)	Prospective Short Circuit Current	Parallel wiring	Isccr	25kA rms with 125A fuses
g)	Operating Temperature		Tu	- 40° C to + 80° C
h)	Temporary Overvoltage -TOV	L-N	U t	335V / 5sec
i)	Temporary Overvoltage -TOV	N-PE	U t	1200V / 200ms

CLASS II/Type 2 SPDs must provide a 1years warranty against manufacturing defects.

7.0 DISTRIBUTION BOARD / CONSUMER UNIT

CLASS III/Type 3 - SPDs selected shall comply to the combine waveform for open circuit voltage (6kV-1.2/50us) and short circuit current (3kA-8/20us) test to protecting end equipment from surges.

The SPD internal connection shall offer comprehensive common and differential mode protection for series / parallel connection.

The SPD protection modules for L-N shall feature SINGLE heavy duty zinc oxide varistor in combination with high discharge capacity "SPARK-GAP" technology protection module for N-PE conductor. It feature a "Y" protection circuit with a combine SPD monitoring and disconnection device for safety and prevention of fire. The plug-in modules interlock in position at the prewired base and neither vibration nor strong electromagnetic forces during discharge can loosen the connection.

The SPD install shall coordinate with the RCD/ELR and protection against indirect contact shall remain effective in the event the SPD failed; in accordance to MS IEC 60364-5-53:2003 if install after the RCD/ELR. NO Leakage Current from the SPD shall not cause unnecessary interruption of the RCD/ELR.

Specification as follows:

a)	Nominal Discharge Current (8/20us)	L-N/E per module	I n	3KA /module
b)	Total Discharge Current (8/20us)	L1+L2+L3+N-PE	I total	8KA
c)	Combine impulse	L1+L2+L3+N-PE	Uoc total	16.0KV
d)	Voltage Protection Level at In/Imax	L-N	U p	<1.50KV
e)	Voltage Protection Level at In/Imax	N-PE	U p	< 1.50KV
f)	Max continuous operating voltage		Uc	255Vac
g)	Nominal Load		I L	25amp (series connection)
h)	Prospective Short Circuit Current	Parallel wiring		6KA rms
	Withstand using 25A Fuses / CB			
i)	Operating Temperature		Tu	- 40° C to + 80° C
j)	Temporary Overvoltage -TOV	L-N	U t	335V / 5sec
k)	Temporary Overvoltage -TOV	N-PE	U t	1200V / 200ms

CLASS III/Type 3 SPDs must provide a 1years warranty against manufacturing defects.

Electrical Board	Location	Specifications
MSB	(within same building)	**SPD Class I + II / Type 1 + 2 SPD** ('3+1' Configuration to Figure K.3 of IEC 61643-12 Annex K) i. I_{imp}, L-N = 25kA (10/350µs) per pole ii. I_{imp}, N-PE = 100kA (10/350µs) iii. I_{SSCR} = 50kArms iv. $U_p \leq 1.5kV$ @ I_{imp} (L-N) ; $Up \leq 1.5kV$ @ I_{imp} (N-PE) v. Back-up Fuse = 315A, 3P NH Gg Fuse vi. I_n, L-N = 25kA (8/20µs) per pole vii. I_n, N-PE = 100kA (8/20µs)
SSB (Three Phase)	(within same building)	**SPD Class II / Type 2 SPD** ('3+1' Configuration to Figure K.3 of IEC 61643-12 Annex K) i. I_n (L-N) = 20kA (8/20µs) per pole ii. I_n (N-PE) = 80kA (8/20µs) iii. I_{max} = 40kA (8/20µs) iv. I_{SSCR} = 25kArms v. $U_p \leq 1.50kV$ @ I_n vi. Back-up Fuse = 125A, 3P Cyl gG Fuse
DB (Three Phase)	(located in another building)	**SPD Class I + II / Type 1 + 2 SPD** ('3+1' Configuration to Figure K.3 of IEC 61643-12 Annex K) i. I_{imp}, (L-N) = 12.5kA (10/350µs) per pole ii. I_{imp}, (N-PE) = 50kA (10/350µs) iii. I_{SSCR} = 25kArms iv. $U_p \leq 1.50kV$ @ I_{imp} v. Back-up Fuse = 160A, 3P NH Gg Fuse vi. I_n, L-N = 25kA (8/200µs) per pole vii. I_n, N-PE = 100kA (8/20µs)
DB (Single Phase)	(within same building)	**SPD Class III / Type 3 SPD** ('1+1' Configuration to Figure K.3 of IEC 61643-12 Annex K) i. I_n, (L-N) = 3kA (8/20µs), U_{oc} = 6kV (1.2/50us) ii. I_n, (N-PE) = 12kA (8/20µs) iii. I_{max} = 10kA (8/20µs) iv. I_{SSCR} = 10kArms v. $U_P \leq 1.50kV$ @ I_n vi. Back-up fuse = 25A, 3P Cyl gG Fuse

Electrical Board	Location	Specifications
DB (Three Phase)	(located in another building)	**SPD Class I + II / Type 1 + 2 SPD** ('3+1' Configuration to Figure K.3 of IEC 61643-12 Annex K) viii. I_{imp}, (L-N) = 12.5kA (10/350µs) per pole ix. I_{imp}, (N-PE) = 50kA (10/350µs) x. I_{SSCR} = 25kArms xi. $U_p \leq 1.50kV$ @ I_{imp} xii. Back-up Fuse = 160A, 3P NH Gg Fuse xiii. I_n, L-N = 25kA (8/200µs) per pole xiv. I_n, N-PE = 100kA (8/200µs)
DB (Three Phase)	External Cowered Walkway	**SPD Class I + II / Type 1 + 2 SPD (Supply from Feeder Pillar)** ('3+1' Configuration to Figure K.3 of IEC 61643-12 Annex K) i. I_{imp}, (L-N) = 12.5kA (10/350µs) per pole ii. I_{imp}, (N-PE) = 50kA (10/350µs) iii. I_{SSCR} = 25kArms iv. $U_p \leq 1.50kV$ @ I_{imp} v. Back-up Fuse = 160A, 3P NH Cyl gG Fuse vi. I_n, L-N = 12.5kA (8/200µs) per pole vii. I_n, N-PE = 50kA (8/20µs)
Feeder Pillar	External	**SPD Class I + II / Type 1 + 2 SPD** ('3+1' Configuration to Figure K.3 of IEC 61643-12 Annex K) i. I_{imp}, (L-N) = 12.5kA (10/350µs) per pole ii. I_{imp}, (N-PE) = 50kA (10/350µs) iii. I_{SSCR} = 25kArms iv. $U_p \leq 1.50kV$ @ I_{imp} v. Back-up Fuse = 160A, 3P Cyl gG Fuse vi. I_n, L-N = 12.5kA (8/20µs) per pole vii. I_n, N-PE = 50kA (8/20µs)

END OF SECTION

EARTH - EARTHING

CONTENTS

EART - EARTHING

1.0 GENERAL

1.1 Work Description

The system shall be a common earthing system as described in the Specification and as shown on the Drawings. Individual earthing systems shall be provided as follows prior to any connections into a common earthing system:

a) HV Transformer Electrical Earthing
b) HV Switchgear Electrical Earthing
c) LV Panel Electrical Earthing
d) Generator Earthing;
e) MDF and SDF Earthing;

Sufficient numbers of electrodes shall be driven into the ground at a distance apart of not less than twice the driven length of electrodes. Earth electrodes of individual earthing systems shall be connected together underground so that the overall earth resistance shall be less than 1 ohm for each individual earthing system.

The numbers of earth electrodes on Drawings are indicative - only but in any case it shall not be less than two. The Contractor shall test the resistivity of soil at site. Exact number of earth electrodes shall be determined by the Contractor to achieve the earth resistance value subject to Consultant or his representative approval. The complete earthing installation is designed to achieve the earth resistance value required.

The Contractor shall inform the Consultant or his representative before driving copper earthing rods into the ground so that he may supervise the operation. Driving shall be carried out only in the presence of the Consultant or the representative and all rods shall be submitted for the examination before use.

1.2 Standards

Complete earthing system shall be designed and constructed in accordance with the latest revision of the following standards and the appropriate BS/IEC;

Standards	Document Titles
BS EN 62305-1:2011	Protection against Lightning. General Principals
BS EN 50522:2010	Earthing of Power Installations exceeding 1kV A.C.
IEEE 80: 2013	IEEE Guide for Safety in AC Substation Grounding

The design of the Earthing System shall also conform to the requirements of all relevant local codes, as applicable, together with the additional requirements referred to in this Specification and Drawings, whichever is the more stringent and acceptable to the Consultant or his representative.

In the adoption of standards and requirements, the Contractor shall take the following precedence:

a) Local codes of practice;
b) Specification;
c) Drawings;
d) International standards and requirements.

1.3 Submission

All technical submissions shall be accepted by the Consultant or his representative prior to the respective stages of construction.

As minimum requirement, the submission shall include the following:

a) Equipment Schedule, including all manufacturers' data;
b) Shop Drawings and Sample Submission;
c) Builder's work requirements;
d) Testing procedures and report format for testing of the earth electrodes and/or earth strips;
e) As-Built drawings with Professional Engineer Endorsement

2.0 EARTHING SYSTEM

2.1 General

Individual earthing system shall comprise the complete earth electrodes/rods, earth inspection chambers/pits, earth leads/ conductors, main earth terminals etc.

Exact locations and quantities of earth electrodes shall be determined after the on-site measurements of soil resistivity. Earth inspection chambers shall be used to protect the electrodes, which shall be connected back to the main earth terminals by earth leads as specified in the Drawings.

The earth mats shall comprise the complete earth electrodes, earth strips/grids, earth inspection chambers, earth leads, main earth terminals, earth test link boxes at ground level, etc. Under this circumstance, each individual earthing system shall have at least two earth leads connecting its main earth terminal directly to an earth electrode underground as specified.

In the case where drilling is required to take the earth rods or copper tapes below ground level, a specified earth resistance enhancement compound shall be added into the bored holes and a mixture at 60% bentonite and 40% of gypsum to 125% of water mixed to give thick slurry. It shall be grouted into the holes prior to inserting of copper rods or copper tapes, and be allowed to solidify. The hiring of machine drilling equipment and the grouting as described above shall be provided by the Contractor.

The earthing system shall be formed from high conductivity annealed copper tapes complying with BS EN 13601:2013 or single core PVC insulated copper cables as specified, where appropriate.

Copper tapes shall be provided where indicated on the Drawings.

All PVC insulated copper cables, copper tape clips, holdfasts, clamps, earth rod clamps, etc. shall be supplied by the same manufacturer of the copper tapes and rods.

All earthing products/accessories shall be approved type.

The mating surface of all tapes at joints etc shall be tinned before clamping and all joints shall be tinned, riveted and soldered. All connectors to electrical apparatus shall be made by a bolted connection in a visible and accessible position.

All joints in exposed section shall be protected against corrosion and the ingress of moisture by application of two coats of an approved anti-corrosion paint.

PVC insulated copper cables/copper tapes shall be secured with appropriate saddles i.e size, type etc, at intervals not exceeding 600 mm and the PVC insulated copper cables/copper tapes shall be supplied in long unbroken lengths to avoid unnecessary jointing.

The Contractor shall furnish and install a complete system as specified, with all necessary apparatus and equipment, wiring, bonding and required to ensure completion of a quality and excellent working system. Notwithstanding the detailed information contained in this specification it is the responsibility of the Contractor to supply a working overall system.

The system shall be a common earthing system. Individual earthing systems shall be provided where applicable to any connections into a common earthing system:

a) Protective / Frame (Normal) Earthing
b) Equipment (Clean) Earthing, and
c) System (Neutral) Earthing.

The earthing system shall generally comprise earthing bars, copper tapes or cables and connections to metallic equipment to ensure equipotential system is achieved.

All linear loads shall be grounded on the Normal earth and non-linear loads such as electronic equipment, telecommunication equipment, SCADA equipment shall be grounded on the Clean earth. All individual earthing systems described above shall be connected together at the common ground to achieve equipotential level.

Earthing conductors shall not be in contact with reinforcement bars of the structure to avoid any stray current problems.

2.2 Earth Electrode

Earth electrode rods shall be 16 mm diameter extensible copper cladded steel type with internal screw and socket joints, hardened steel tip, driving head and connection clamp.
Copper clad steel rods shall have cores of low carbon steel with a tensile strength of approximately 600 N/mm2 and steel quality of not less than grade 43 of BS EN 10025-1:2004. The cladding should be of 99.9% pure electrolytic copper molecularly bonded to the steel core. The radial thickness of the copper should be less than 0.25mm.

Couplings for copper-clad steel rods should be made from silicon bronze alloy of grade CS101 of BS EN 12163:2016.

Couplings for each section of the rod shall be of bronze type, threaded to fit the rod sections. Driving studs shall be used when driving the electrode into the ground. Earth values shall be measured and recorded before coupling and driving in the next section. A minimum of two electrode pits shall be provided. Additional earth rods shall be driven in if necessary to attain the required effective earth values.

Clamping of the earth leads to the earth rod shall be made by earth clamp. The clamps shall be of cast bronze type, capable of providing a high pressure contact between the earth rod and the earth leads to achieve a low contact resistance.

When two or more electrodes are driven to form a group, the heads of the electrodes in the group shall be bonded to each other by means of either a 150mm2 stranded copper cables or a 50mm x 6mm copper tape laid at a depth of at least 600 mm in soil.

All earth electrode penetrations through basement water proofing membranes shall be provided with manufacturer's recommended water seal insert sleeve approved by Contractor. The installation of the water seal insert sleeve shall be under the supervision and endorsed by the manufacturer's representative to ensure the installation comply with the manufacturer installation detail.

2.3 Earth Inspection Chamber

As a minimum requirement, every earth electrode shall be fitted with a heavy-duty pre-cast concrete inspection chamber/pit complete with heavy-duty hinged cover.

For earth electrodes located outside or on the apron of the building, earth inspection chambers shall extend to a depth of not less than 300 mm below finished ground level and kept free of soil. For earth electrodes located inside building, earth electrodes shall be buried not less than 100mm below the floor slab structure. Each earth electrode shall be clearly marked 'SAFETY ELECTRICAL EARTH CONNECTION - DO NOT REMOVE'.

The chamber and cover shall be heavy duty design to consider the traffic load at the location of installation. The cover shall be recessed cover to receive the Architectural floor finish at the location of installation.

2.4 Earth Lead

Earth leads, also commonly known as earth conductors, shall be used for the final connection between the earth electrodes and the main earth terminals for station and final connection between the earth electrode and the earth plate for via-duct.

To minimize electrolytic corrosion, no aluminum conductors shall be allowed for the earth leads.

Unless otherwise specified, earth leads shall be of 50mm x 6mm bare copper tapes or 150 mm2 bare stranded copper cables

For via-duct, unless specified, the earth lead shall be embedded in concrete at min 10mm depth.

2.5 Main Earth Terminal

Main earth terminals shall be provided for the termination of each earthing system. 50 mm x 6 mm HDHC copper earth bars of not less than 300 mm in length shall be installed in the respective plant rooms / switch rooms at a height of 300 mm above finished floor level. The insulators shall be approved type. Interconnection between plant rooms / switch rooms and connection to earth electrodes shall be as per the Drawings and/or as required to complete the installation.

Suitable earthing terminals shall be provided in all the equipment housings, switchgear enclosures, relayed and instrument casings and all other electrical metalwork for bonding to earth.

The earth connections for all sections of the installation shall be electrically continuous throughout back to the corresponding main earth terminals.

2.6 Connections

Buildings shall be provided with full equipotential bonding to limit the voltage that may be experienced by personnel during electrical fault conditions. Equipotential bonding shall comply with the relevant requirements of MS IEC 60364 and BS 7671.

Main equipotential bonding shall be provided between the main earth network and all large or extensive extraneous metal objects not already bonded to earth by electric circuit protective earth conductors. These shall include, but not be limited, the following:

a) All external metallic service pipes
b) Fire main pipes
c) Ventilation ductwork
d) Air conditioning ductwork
e) Water pipework
f) Steel floor plates
g) Station/substation lifting tackle
h) Cable containment system
i) Ceiling grid
j) Window frame
k) Metal door frame
l) Handrails/Cat ladders
m) Wire mesh of transformer bay

External metallic service pipes shall be bonded at or as close as possible to the point of entry to the building. Services such as fire mains, which between sub stations and ancillary building, shall be bonded at each station/ancillary building.

It shall not be assumed that large or extensive extraneous metal objects, such as fire main pipework, are electrically continuous throughout. Supplementary bonding should therefore be considered where such metal objects are simultaneously accessible with the metalwork associated with electrical equipment.

Supply and installation of subsidiary earth conductors and accessories, including tee-off conductors inside individual equipment rooms from the main earth conductors and final connection at the earth terminal of the apparatus to be earthed, shall be provided.

All metal parts including metal water tank, pipework and cable trays, other than those forming parts of any electrical circuit, shall be effectively connected onto the earth system. Metal parts of raised floor system shall also be effectively bonded.

The earth conductors shall provide a metallic path between all points of the earthing system.

All switch/distribution boards shall be earthed using an earth strip/conductor to the main earth network. The main earth network shall also be used by other services for earthing their equipment.

The Contractor shall supply and install an earth connection bar adjacent to all service chambers, manholes for earthing of water pipes.

Unless otherwise specified, low voltage switchboards and MCCs shall be connected to the earth system by two conductors with cross-sectional area of not less than 300mm^2 at both ends of the switchboards and MCCs.

All equipment, plant or pipework, to be earthed shall be connected to the main earth conductor by protective conductors.

Unless otherwise specified, the casing of small low power consuming devices may be grouped on the protective conductor provided that the cross-sectional area of the said conductor is not less than 70mm^2.

Fixing to buildings shall be by means of copper or brass clamps with brass screws and non-fibrous wall plugs. Conductors fixed in visible locations shall be run only in vertical and horizontal directions. Changes of direction in the plan of the conductors shall be by right-angled joints. Folding of the conductor shall not be permitted.

Running joints shall be either welded or brazed such that the resistance of a short section containing the joint shall be not greater than that of a similar length of un-jointed conductor. The Contractor or his representative may require any joint to be tested to prove compliance with this requirement.

No drilling of the earth bar shall be permitted except in termination. Joints and connections to the earth system shall be so effected as to avoid undue reduction of the current carrying capacity. Precautions shall be taken to ensure that available contact area is fully utilized in all connections to plant and equipment. The contact faces of earth terminals shall be cleaned before connections are made to the earth system. The earth bar shall be tinned. Joints to the switchboards and sub-switchboards may be by bolts and the area of contact shall be large and the joints shall be tight.

Earth connections for all items of equipment shall be made between the equipment and the distribution board feeding it.

Where conductors could come into contact with metalwork at or near earth potential, they shall either be bonded solidly or shall be insulated to withstand an alternating potential difference of 500V r.m.s.

The armouring of all armoured cable shall be connected to the main earth system.

All connections between earth conductors and equipment or plant shall be by bolts or studs so arranged that the resistance between the equipment or plant and the earth conductor shall not exceed 0.01 ohms.

No earth stud or bolt shall have a cross-sectional area at the base of the threads less than 15mm2.

The minimum size of earth wire shall be as defined in BS 7671 or as shown on the Drawings, whichever is the greater.

Particular care shall be taken on cable termination boxes to ensure that the cable sheath and armour is adequately bonded to the frame of the item of plant to which the cable is connected. If the earth continuity through the cable termination gland is inadequate then a special copper connection shall be made between the equipment and the cable sheath and armour.

The earth system shall not be permitted to carry single phase load current. Earthing conductors shall be sized to carry the maximum earth fault current for 3 seconds.

For via-duct, all connections / joints on the earth wires, earth electrodes, rebars, shall be exothermically or butt weld or brazed such that the resistance of the section containing the joint shall not exceed that of an equivalent length at unjointed conductor. Any joint so made may be required to be tested to prove compliance with the requirement.

The Sub Contractor shall permit provision for the earth wires to be connected to earth plates (supplied and installed by others as indicated in the Drawings.

The contact faces of all protect conductors shall be cleaned and tinned before connections are made.

3.0 EARTH BONDING

3.1 Circuit Protective Conductor

Circuit protective conductor (CPC) is a system of conductors joining together all exposed conductive parts and connecting them to the main earth terminal.

The purpose of circuit protective conductor is to provide a path for earth fault circuit so that the protective device will operate to remove dangerous potential difference during a fault condition.

The circuit protective conductors shall take the form of separate cable with a sheath in green/yellow color or copper tape of minimum size 25mm x 3mm.

All exposed non-current carrying metal parts of light fittings, switchgears, motor, enclosures, etc. shall be effectively earthed by circuit protective conductors for earth continuity protection.

For equipment where an earth terminal is provided, the earth continuity wire shall be firmly clamped. Where no earth terminal is provided, the exposed metal part shall be cleaned of paint and surface rust before welding the earth continuity lead.

The minimum size of the principal protective conductors shall be 150mm2.

The scope of works for mechanical equipment i.e Air-conditioner panels, chiller etc, and the earthings shall be by Contractor.

Circuit protective conductors shall be provided in electrical and mechanical rooms and along the routes for the bonding of all exposed conductive parts and extraneous conductive parts. A suitably sized earth terminal shall be provided at each zone of the building for this purpose.

All exposed conductive parts shall be effectively connected in an approved manner to the principal protective conductors. The circuit protective conductors shall be single core copper cables or high conductivity annealed copper tapes specified. Unless otherwise specified, the minimum cross-sectional area of the circuit protective conductors shall be selected in accordance with IET Wiring Regulation:

Cross Sectional Area (mm^2) of Phase Conductors (S)	**Cross Sectional Area of Earthing or Protective Conductor ($mm^{2)}$**
$S \leq 16$	S and $\geq$ 4 mm^2, if no mechanical protection
$16 < S \leq 35$	16
$S > 35$	S/2

3 Installation at Main Building

a) Earth Mat

Two principal earth conductors, which are connected to earth mats at both ends of stations, shall be provided at each underground and elevated station.

For each earth mat, two principal earth conductors shall be provided above the finished floor screed. The Contractor shall interconnect the two principal earth conductors above the finish floor screed. A minimum of two bolted copper links shall be provided at the top of the principal conductors above the finished floor screed. The links shall form the Principal Earth Terminals. Each link shall be of copper and shall have minimum cross- sectional area of 300mm2. The links shall form the connection point to the building main earth network. The links shall be appropriately labeled “Principal Main Earth Connection / Terminal”.

Each principal earth conductor entering through the base slab shall be equipped with the waterproof earth rod / electrode seal assembly.

For each test electrode, one principal earth conductor above the finished floor screed shall be provided. Bolted copper links as described in above shall be provided at the

top of the principal conductor above the finished floor screed. The link shall be labeled "Test Electrode Connection".
At each test electrode, the test electrode shall be equipped with inspection test pit and waterproof earth rod / electrode seal assembly.

The physical arrangement of the links and their connections shall be such as to protect them against possible mechanical damage.

b) Main Earth System
From the Principal Main Earth Connection/Terminal, a main earth conductor system shall be provided. The main earth system, which consists of two vertical rising main conductors with tee-off main conductors in each level of the building as shown on the Drawings, shall be supplied and installed by the Contractor.

The vertical rising main conductors and tee-off main conductors shall be hard drawn copper tape conductors.

The tee-off main conductors of the main earth network shall be routed close to all plantrooms provided with main earth terminals at each level of the building as shown on the Drawings. The tee-off main conductors shall be connected to the two vertical rising main conductors at each level of the building to form a closed ring network. Sub tee-off earth conductors shall be connected from the tee-off main conductors to the main earth terminals provided in the plantrooms as shown on the Drawings. The sub tee-off earth conductors and main earth terminals of sizes as shown on the Drawings shall be provided by the Contractor. The sub tee-off earth conductors and main earth terminals shall be hard drawn tinned copper tapes.

All joints and connections for the main earth network including vertical rising main conductors, tee-off main conductors and sub tee-off earth conductors shall be either welded or brazed connections.

3.2 Earth Enhancement Material

Earth enhancement material is a superior conductive material that improves earthing effectiveness, especially in areas of poor conductivity (rocky ground, areas of moisture variation, sandy soils etc.). It improves conductivity of the earth electrode and ground contact area. It shall have following characteristics: -

a) shall mainly consist of Graphite.
b) shall have high conductivity, improves earth's absorbing power and humidity retention capability.
c) shall be non-corrosive in nature having low water solubility but highly hygroscopic.
d) shall have resistivity of less than 1.0 ohms-meter. Resistivity shall be tested to IEC 6256, cube of the material and checking resistance of the cube at the ends. The supplier shall arrange for such testing at the time of supply, if so desired. Necessary certificate from National/ International lab for the resistivity shall also be submitted.
e) shall be suitable for installation in dry form or in a slurry form.
f) shall not depend on the continuous presence of water to maintain its conductivity.
g) Low impedance conductive concrete cube when harden and cube, it shall be strong and has a greater comprehensive strength than a grade 25 ordinary cement with 25 N/m2 compression strength and conductivity of 1.0 ohms-meter.

h) shall be permanent & maintenance free and in its "set form", maintains constant earth resistance with time.
i) Accredited laboratory test report shall be submitted; earthing electrode embedded in conductive concrete with a short circuit time withstand current required for 6kV high voltage impulse test applied for 3 seconds to determine the electrical impedance in compliance to IEC 62561-7:2011
j) shall be thermally stable between -10^0 C to $+60^0$ C ambient temperatures.
k) shall not dissolve, decompose or leach out with time.
l) shall not require periodic charging treatment nor replacement and maintenance.
m) shall be suitable for any kind of electrode and all kinds of soils of different resistivity.
n) shall not pollute the soil or local water table and meets environmental friendly requirements for landfill.
o) shall not be explosive
p) shall not cause burns, irritation to eye, skin etc.
q) Marking: The Earth enhancement material shall be supplied in sealed, moisture proof bags. These bags shall be marked with Manufacturer's name or trade name, quantity etc.

3.3 Backfill material

The excavated soil is suitable as a backfill but should be sieved to remove any large stones and placed around the electrode taking care to ensure that it is well compacted. Material like sand, salt, coke breeze, cinders and ash shall not be used because of its acidic and corrosive nature.

4.0 COLUMN EARTHING SYSTEM

The installation of earth wire shall include the bonding between earth wire and pile reinforcement bar of the column. The Contractor shall choose the pile reinforcement bar with least resistance and bonding between the earth wire and pile reinforcement bar shall be by means of exothermic welding. All earth wires shall be embedded in the structure for safety and vandalism prevention measures. Upon completion of the installation of earth plate, the Contractor shall cut the remaining unused earth wires (pig tails) on the column and cover with epoxy coating of min 2mm thickness accordingly.

The Contractor shall ensure sufficient numbers of electrodes shall be driven into the ground at a distance apart of not less than the driven length of electrodes. The numbers of earth electrodes on Drawings are indicative only but in any case it shall not be less than two. Exact number and location of earth electrodes shall be determined by the Contractor to achieve the earth resistance value subject to Engineer approval. The complete earthing installation is designed to achieve the earth resistance value required.

The Contractor shall inform the Engineer or his representative before driving copper earthing electrodes into the ground so that he may supervise the operation. Driving shall be carried out only in the presence of the Engineer or the representative and all rods shall be submitted for the examination before use.

4.1 Earthing System

Individual earthing system shall comprise earth electrodes/ concrete encased electrodes, earth inspection chambers/pits, earth wires/conductors embedded in concrete, exothermic welding, etc.

Exact locations and quantities of earth electrodes shall be determined after the on-site measurements of soil resistivity. Earth inspection chambers shall be used to protect the electrodes as specified in the Drawings.

In the event where parallel earth electrodes are required, the earth electrodes (earth chambers) must be spaced at a distance at least equal to their driven depth.

The welding / bonding of earth wires to the pile reinforcement bar shall also be made exothermically to provide high quality electrical connections.

The earthing system shall be formed from high conductivity annealed copper tapes complying with BS 1432 or single core PVC insulated copper cables as specified, where appropriate.

All PVC insulated copper cables, copper tape clips, holdfasts, clamps, earth rod clamps, etc. shall be supplied by the same manufacturer of the copper tapes and rods.

All earthing products/accessories shall be approved type.

All joints in exposed section shall be protected against corrosion and the ingress of moisture by application of two coats of an approved anti-corrosion paint.

The PVC insulated copper cables/copper tapes shall be supplied in long unbroken lengths to avoid unnecessary jointing.

END OF SECTION

ELPS - LIGHTNING PROTECTION SYSTEM

CONTENTS

ELPS - LIGHTNING PROTECTION SYSTEM

1.0 LIGHTNING PROTECTION SYSTEM

1.1 Scope of Work

The works covered under this contract comprise the complete supply, installation, testing and commissioning of the Lightning Protection System.

Contractor shall furnish and install a complete system as specified, with all necessary apparatus and equipment, wiring, etc., required to ensure, on completion, a system of professional quality in excellent working order, as specified herein and as shown. Notwithstanding the detailed information contained in this specification, it is the responsibility of Contractor to supply a working overall system.

1.1.1 Standards

i)	MS IEC / IEC 62305-1 to -4:2010	Standard for Lightning Protection System
ii)	MS IEC / IEC 62561-1:2017	Lightning Protection System Components (LPSC) Pt.1 Requirement for Connection Components
iii)	MS IEC / IEC 62561-2:2018	LPSC Pt.2 Requirements for Earth Conductors and Earth Electrodes
iv)	MS IEC / IEC 62561-3 :2017	Requirements for Isolating Spark-Gaps (ISG)
v)	MS IEC / IEC 62561-4 :2017	Requirements for Surface Conductor Fasteners (a.k.a.saddle)
vi)	MS IEC / IEC 62561-5 :2017	Requirements for Earth electrode inspection housings & Earth Electrode Seals
vii)	MS IEC / IEC 62561-6 :2018	Requirements for Lightning Strike Counter(LSC)
viii)	MS IEC / IEC 62561-7 :2017	Requirements for Earthing Enhancing Compounds
ix)	BS EN 12163 : 2016	Copper & Copper Alloys – Rods for General Purposes

1.2 Class of Lightning Protection System

There are four classes of Lightning Protection Level (I to IV) in MS IEC 62305-1 as shown in Table 1 and shall be selected on the basis of a Risk Management.

LPS	Class of LPS
I	I
II	II
III	III
IV	IV

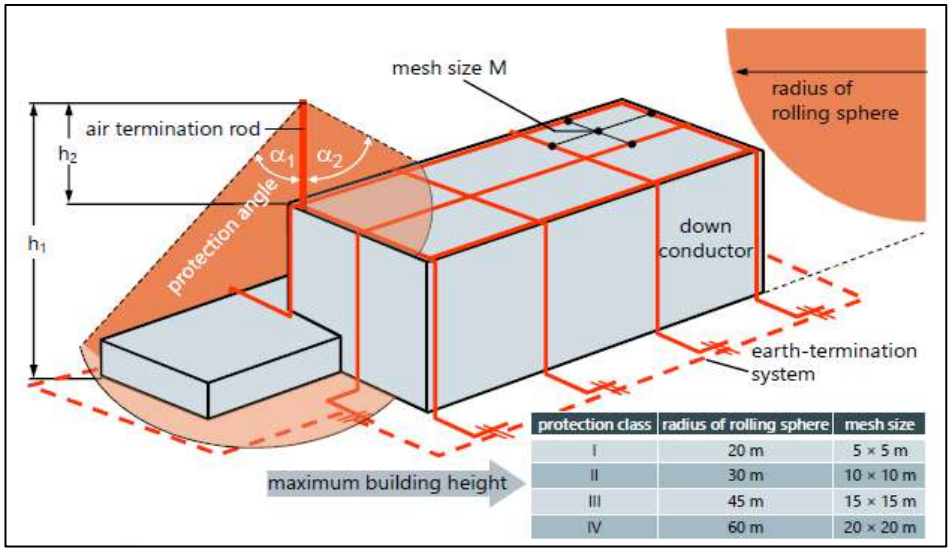
Table 1 - Relation between Lightning Protection Level (LPL) and Class of LPS (MS IEC 62305-1)

Risk Analysis per IEC / MS IEC 62305-2 must be done for each individual building to determine and justify the LPS level required for adequate protection. R1, Risk of loss of human life, with LPS solution must be less than $1x10^{-5}$. R2, R3 & R4 are project dependent but the minimum risk shall met IEC 62305-2 requirements.

The air termination system components can be with one or any combination of the following methods:

- The Mesh method
- The Rolling Sphere method
- The Protection Angle method

Methods of positioning of air termination system



The values of each methods in each class of LPS are shown in Table 2

		Protection Method	
Class of LPS	Rolling sphere radius(m)	Mesh size (m)	Protection angle ȁ
I	20	5 X 5	
II	30	10 X 10	See figures below
III	45	15 X 15	
IV	60	20 X 20	

Rolling sphere radius, protection angle, mesh size and typical distance between down conductors

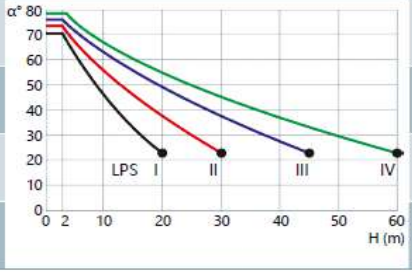
Class of LPS	Protection method			Typical distances between down conductors (m)
	Rolling sphere radius r (m)	Protection angle α (°)	Mesh size w (m)	
I	20		5 x 5	10
II	30		10 x 10	10
III	45		15 x 15	15
IV	60		20 x 20	20

Table 2 - Maximum values of rolling sphere radius, mesh size and protective angle corresponding to the class of LPS.

1.3 Air Termination System

The Air Termination system shall be a network of vertical and horizontal conductors as shown in the drawings. The air terminals or vertical finials must be provided if specified in the drawings.

For any structure taller than 60m, a lateral air termination system shall be installed on the upper part of topmost 20% of the height of the structure for protection against side flashes to the side of structure. When there is a metal façade, it must be bonded and form part of the air termination system.

If there are structures higher than 120m, all parts which are exposed to danger should be protected.

If specified, air termination system other than air terminals shall be of 25mm x 3mm annealed copper tape. If other materials are specified, it shall conform to Table 5 & 6 of MS IEC 62305-3

	Use			Corrosion		
Material	In Open air	In earth	In concrete	Resistance	Increased by	May be destroyed by galvanic coupling with
Copper	Solid Stranded	Solid Stranded As coating	Solid Stranded As coating	Good in many environments	Sulphur compounds Organic materials	-
Hot galvanized steel	Solid	Solid	Solid	Acceptable in air, in concrete and in benign soil	High chlorides content	Copper
Stainless Steel	Solid Stranded	Solid Stranded	Solid Stranded	Good in many environments	High chlorides content	-
Aluminium	Solid Stranded	Unsuitable	Unsuitable	Good in atmospheres containing low concentrations of sulphur and chloride	Alkaline solutions	Copper
Lead	Solid As coating	Solid As coating	Unsuitable	Good in atmospheres with high concentration of sulphates	Acid soils	Copper Stainless Steel

NOTE 1 This table gives general guidance only. In special circumstances more careful corrosion immunity considerations are required (see Annex E).

NOTE 2 Stranded conductors are more vulnerable to corrosion than solid conductors. Stranded conductors are also vulnerable where they enter or exit earth/concrete positions. This is the reason why stranded galvanized steel is not recommended in earth.

NOTE 3 Galvanized steel may be corroded in clay soil or moist soil.

NOTE 4 Galvanized steel in concrete should not extend into the soil due to possible corrosion of the steel just outside the concrete.

NOTE 5 Galvanized steel in contact with reinforcement steel in concrete may, under certain circumstances, cause damage to the concrete.

NOTE 6 Use of lead in the earth is often banned or restricted due to environment concerns.

Table 5 – LPS Materials and conditions of use

Material	Configuration	Mininum cross-sectional areas mm^2	Comments [10]
Copper	Solid tape	50 [8]	2 mm min. thickness
	Solid round [7]	50 [8]	8 mm diameter
	Stranded	50 [8]	1.7 mm min. diameter of each strand
	Solid round [3], [4]	200 [8]	16 mm diameter
Tin plated copper [1]	Solid tape	50 [8]	2 mm min. thickness
	Solid round [7]	50 [8]	8 mm diameter
	Stranded	50 [8]	1.7 mm min. diameter of each strand
Aluminium	Solid tape	70	3 mm min. thickness
	Solid round	50 [8]	8 mm diameter
	Stranded	50 [8]	1.7 mm min. diameter of each strand
Aluminium alloy	Solid tape	50 [8]	2.5 mm min. thickness
	Solid round	50	8 mm diameter
	Stranded	50 [8]	1.7 mm min. diameter of each strand
	Solid round [3]	200 [8]	16 mm diameter
Hot dipped galvanized steel [2]	Solid tape	50 [8]	2.5 mm min. thickness
	Solid round [9]	50	8 mm diameter
	Stranded	50 [8]	1.7 mm min. diameter of each strand
	Solid round [3] [4] [9]	200 [8]	16 mm diameter
Stainless steel [5]	Solid tape [6]	50 [8]	2 mm min. thickness
	Solid round [6]	50	8 mm diameter
	Stranded	70 [8]	1.7 mm min. diameter of each strand
	Solid round [3], [4]	200 [8]	16 mm diameter

Hot dipped or electroplated minimum thickness coating of 1 µm.

The coating should be smooth, continuous and free from flux stains with a minimum thickness coating of 50 µm.

Applicable for air-termination rods only. For applications where mechanical stress such as wind loading is not critical, a 10mm diameter, 1m long maximum air-termination rod with an additional fixing may be used.

Applicable to earth lead-in rods only.

Chromium ≥ 16%, nickel ≥ 8%, carbon ≤ 0.07%.

Material	Configuration	Mininum cross-sectional areas mm^2	Comments [10)]
For stainless steel embedded in concrete, and/or in direct contact with flammable material, the minimum sizes should be increased to 78mm^2 (10 mm diameter) for solid round and 75mm^2 (3 mm minimum thickness) for solid tape. 50 mm^2 (8mm diameter) may be reduced to 28 mm^2 (6 mm diameter) in certain applications where mechanical strength is not an essential requirement. Consideration should, in this case, be given to reducing the spacing of the fasteners. If thermal and mechanical considerations are important, these dimensions can be increased to 60 mm^2 for solid tape and to 78 mm^2 for solid round. The minimum cross-section to avoid melting is 16 mm^2 (copper), 25 mm^2 (aluminium), 50 mm^2 (steel) and 50 mm^2 (stainless steel) for a specific energy of 10 000 kj/Ω. For further information see Annex E. Thickness, width and diameter are defined at ± 10%.			

Table 6 – Material, configuration and minimum cross-sectional area of air-termination conductors, air-termination rods, earth lead-in rods and down-conductors

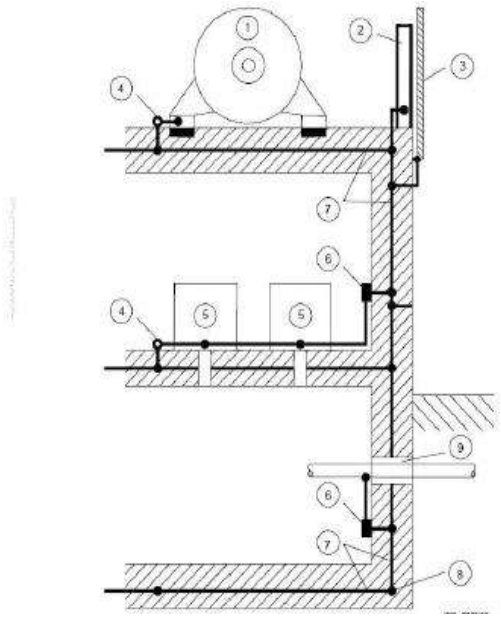


Figure 1 Equipotential bonding in a structure with a steel reinforcement

Key

1. Electric power equipment
2. Steel girder
3. Metal covering of the façade
4. Bonding joint
5. Electrical and electronic equipment
6. Bonding joint
7. Steel reinforcement in concrete (with superimposed mesh conductors)

8. Foundation of earth electrode
9. Common inlet from different services

1.4 Technical Specification

The scope of works under this section outlines the requirements for lightning protection system to cater for the entire Site.

a) The lightning protection system shall be of the enhancing type designed to attract lightning from predetermined volume and to safely convey the lightning current to earth through a known and preferred route.

b) The lightning protection system shall include the following components: as follows: air termination(s), mechanical support(s) down conductor(s), joints and bonding, test joints, performance recording equipment, and an earthing system.

c) The design of the components shall be traceable to field research, laboratory testing fundamental analysis and statistical levels of the lightning event.

d) The air termination shall be of the type that responds dynamically to the appearance of a lightning down conductor by creating free electrons and photo-ionisation between a spherical surface and an earthed central finial

e) The earth system shall not exceed 5 ohms static impedance except with prior written approval by the manufacturer of the lightning protection system.

f) Lightning event counter is to be provided and the lightning protection system shall be radio quiet.

g) Contractor shall provide a computer printout showing the most effective location for installing the system. The computer print-out shall show all backup calculations.

The lightning protection system shall conform to BS EN 62305 and MS IEC 62305 and shall consist of the following principal component parts:

a) air terminations,
b) down conductors,
c) joints and bonds,
d) test joints,
e) earth terminations
f) earth chambers, and
g) earth electrodes.

1.5 Down Conductors and Roof Conductors

Unless specified all down conductors and roof conductors shall be those listed in Table 5, with use cases in line with Table 5 and of dimensions not less than those listed in Table 6. The exposed conductor shall be of Solid Rod type, with fixing intervals in accordance to Table E.1 of IEC 62305-3. Fixing Intervals shall be 1.0m with use of IEC 62561-4 type-tested saddles. All exposed metallic structures shall be bonded to exposed lightning conductors via IEC 62561-1 type-tested clamps.

Each down conductor shall be brought straight down to its own earth termination at ground level, with the least looping possible so as to prevent unduly high electrical stresses during the passage of lightning currents.

Joints of down-conductors shall be done using IEC 62561-1 type-tested clamps of the same or compatible material to the down-conductor the down-runs shall be kept as direct as possible and the utilization of right-angled bends or deep re- entrant loops in the down-runs shall be minimized.

The metal parts of the building structure; i.e. reinforcing bars, handrails, water tank, cooling towers, aluminum frame/cladding, etc., shall be bonded to the down conductor to ensure equipotential is achieved between all metallic objects, minimize the possibility of flashover to adjacent metal objects.

The entire length of the down conductor can be concealed in concrete or surface mounted, clamped to the rebar by IEC 62561-1 clamps at intervals following Table E.1 to ensure maximum down-conductor strength and equipotential to the structural rebars is achieved.

In case of metal deck cladding roof to be used as air termination components, the minimum thickness of metal deck sheets shall comply with Table 3 of MS IEC 62305-3.

If there are different heights in building structure, any air termination system of lower portions down conductors shall be bonded to the down conductor of the taller structure. When the air termination components in a metal deck cladding roof cannot be considered, the air terminations shall be secured and connected to the metal deck roof structure by means on non-metallic make type.

Class of LPS	Material	Thickness [1] t mm	Thickness [2] tt mm
I to IV	Lead		2.0
	Steel (stainless, galvanized)	4	0.5
	Titanium	4	0.5
	Copper	5	0.5
	Aluminium	7	0.65
	Zinc	-	037

[1] t prevents puncture, hot spot or ignition

[2] tt only for metal sheet. If it is not important to prevent puncture, hotspot or ignition problem.

Table 3 – Minimum thickness of metal sheet sheets or metal pipes in air termination system

The metal cladding can be considered as natural air termination components and part of the LPS in accordance of MS IEC 62306-3 provided that

- the electrical continuity between the various parts is made durable (eg. By means of welding, crimping, brazing, clamping, bolting).

- the thickness of the metal sheet is not less than the value of tt given in Table 3 of MS IEC 62305-3. If it is not important to prevent puncture of the sheeting or to consider ignition of any readily combustible material underneath.
- the thickness of the metal sheet is not less than the value t given in Table 3. If it is necessary to take precautions against puncture or to be consider hot spot problems.
- they are not clad with insulating material.

The down conductor shall be installed so that its path is direct as possible between air termination and earth termination system.

Class of LPS	Typical Distance , m
I	5
II	10
III	15
IV	20

Table 4 – Typical values of the distance between down conductors of the relevant class of LPS (MS IEC 62305-3) See Table 4 above.

1.6 Natural down Conductor

A termination joint should be provided on the roof to facilitate the connection of the air termination system and unless the RC foundation is being used as the only earth termination, termination joints should be provided to facilitate the connection with the earth termination system.

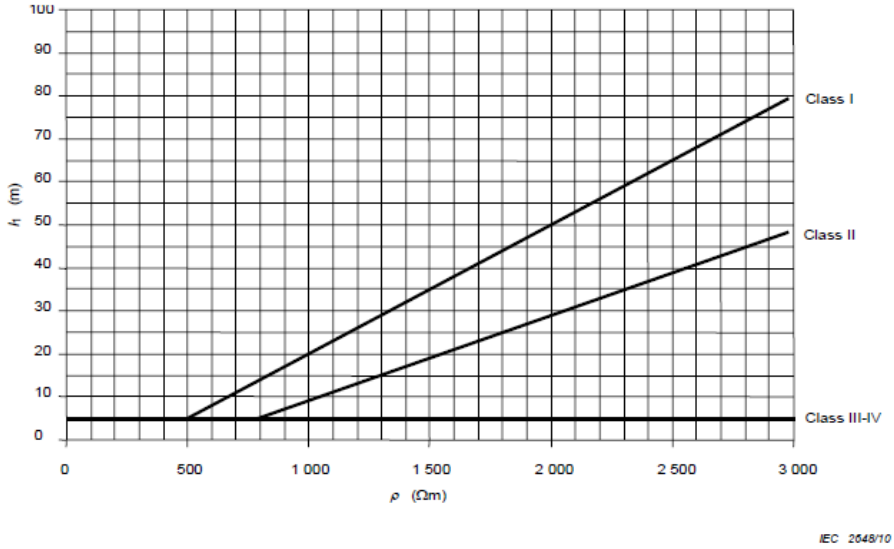
When using the particular steel bar reinforcement as the down conductor, reasonable care should be taken to ensure the rod is located in the same position all the way down to earth. This is to provide a direct electrical route continuously and are adequately earthed. This electrical continuity of the steel bars must be tested each time between the uppermost part floor & every lower floor to ground level.

The steel work in the reinforced concrete structures is considered to be electrically continuous and major part of interconnections of vertical and horizontal bars are to be welded/clamped and securely connected. The connection of vertical bars or horizontal bars shall be not less than 50mm by using the clamping method.

An additional conductor is to be use to enhance the natural down conductor and bonded to reinforcement if the overall electrical resistance is greater than 0.2 Ohms. The additional conductor shall be clamped to reinforcement bars by means of purpose made clamps at 1.0m intervals. This regular electrical continuity for earthing test and bonding must be done simultaneously as work in building construction progress.

1.7 Type-A Earth Terminations

In type A arrangements, the total number of earth electrodes shall be not less than two.



NOTE Classes III and IV are independent of soil resistivity.

Figure 3 – Minimum length l_1 of each earth electrode according to the class of LPS

The minimum length of each earth electrode at the base of each down-conductor is

– l_1 for horizontal electrodes, or
– 0,5 l_1 for vertical (or inclined) electrodes,

where l_1 is the minimum length of horizontal electrodes shown in the relevant part of Figure 3.

The earth electrode shall consist of 316Gr Stainless Steel or Copper materials and diameter as allowed by Table 5 & Table 6 driven in ground. The length of the earth rod shall depend on the LPS Level and the chart as given by Figure 3, under Section 5.4.2.1 in IEC 62305-3 resultant earth resistance and shall not be more than 10 ohms while a resistance of 5 ohms and below is desirable.

The top of earth rod shall be protected from damage by placing it in a shallow recess with a suitable cover. The actual connection of the conductor to the pipe must be accessible and clearly visible when the cover is removed.

In the event parallel earth rod electrodes are required, the earth rods (earth chambers) must be spaced at a distance at least double their driven depth.

The exact number and depth of the earth electrodes for this system shall be determined based on the soil resistivity test results and to achieve the desired ohmic value.

The lighting protection earthing is to be inter-connected to the main earthing grid only when the earth resistance of below 10 ohms is achieved for the lightning protection system.

1.7.1 Type B arrangement

This type of arrangement comprises either a ring conductor external to the structure to be protected, in contact with the soil for at least 80 % of its total length, or a foundation earth electrode forming a closed loop. Such earth electrodes may also be meshed.

NOTE Although 20 % may not be in contact with the soil, the ring conductor must always be completely connected throughout its total length.

For the ring earth electrode (or foundation earth electrode), the mean radius re of the area enclosed by the ring earth electrode (or foundation earth electrode) shall be not less than the value l1:

$$re \geq l1 \quad (1)$$

where l1 is represented in Figure 3 according to LPS class I, II, III and IV.

When the required value of l1 is larger than the convenient value of re, additional horizontal or vertical (or inclined) electrodes shall be added with individual lengths lr (horizontal) and lv (vertical) given by the following equations:

$$lr = l1 - re \quad (2)$$

and

$$lv = (l1 - re) / 2 \quad (3)$$

It is recommended that the number of electrodes shall be not less than the number of the down-conductors, with a minimum of two.

The additional electrodes should be connected to the ring earth electrode at points where the down-conductors are connected and, for as many as possible, equidistantly

Table 7 – Material, configuration and minimum dimensions of earth electrodes a, e

Material	Configuration	Dimensions		
		Earth rod diameter mm	Earth conductor mm^2	Earth plate mm
Copper Tin plated copper	Stranded		50	
	Solid round	15	50	
	Solid tape		50	
	Pipe	20		
	Solid plate			500 × 500
	Lattice plate [c]			600 × 600
Hot dipped galvanized steel	Solid round	14	78	
	Pipe	25		
	Solid tape		90	
	Solid plate			500 × 500

	Lattice plate [c]			600 × 600
	Profile	[d]		
Bare steel[b]	Stranded		70	
	Solid round		78	
	Solid tape		75	
Copper coated steel	Solid round	14 [f]	50	
	Solid tape		90	
Stainless steel	Solid round	15 [f]	78	
	Solid tape		100	

[a] Mechanical and electrical characteristics as well as corrosion resistance properties shall meet the requirements of the future IEC 62561 series.
[b] Shall be embedded in concrete for a minimum depth of 50 mm.
[c] Lattice plate constructed with a minimum total length of the conductor of 4,8 m.
[d] Different profiles are permitted with a cross-section of 290 mm^2 and a minimum thickness of 3 mm, e.g. cross profile.
[e] In case of a type B arrangement foundation earthing system, the earth electrode shall be correctly connected at least every 5 m with the reinforcement steel.
[f] In some countries the diameter may be reduced to 12,7 mm.

1.8 Testing Joints

Each down conductor shall be provided with a testing joint placed in such a position that, while not inviting unauthorized interference, it is convenient for use when testing.

The testing joint (test-clamp) shall be at a height of 2500mm above the building's apron. Exposed down-conductors shall be done using a 5 meter long touch & step potential safe insulated down-conductors that passes the 15 times injection of 100kV 1.2/50us open voltage injection test. The insulated lightning down-conductor shall join from the test joint to earth pit under the apron. The earth pit shall be located away apron.

Embedded Down conductors with a test-joint located 2500mm above the apron level shall have a warning sign at the 1200mm level to warn pedestrians to keep away by at least 3m distance during thunderstorm and rain. For enhanced step-potential safety, the embedded down-conductor shall be connected to an additional earthing ring installed on top of the apron's rebars in a ring around the building at every meter interval before apron casting is done.

1.9 Joints

62305-3 © IEC:2010(E) – 71 –

E.4.3.3 Welding or clamping to the steel-reinforcing rods

The continuity of the reinforcing rods should be established by clamping or welding.

NOTE Clamps conforming to the future IEC 62561 series are suitable.

Welding to the reinforcing rods is only permitted if the civil works designer consents. Th reinforcing rods should be welded over a length not less than 50 mm (see Figure E.5).

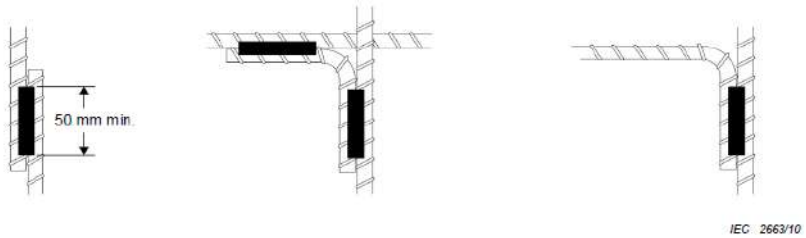


Figure E.5a – Welded joints (suitable for lightning current and EMC purposes)

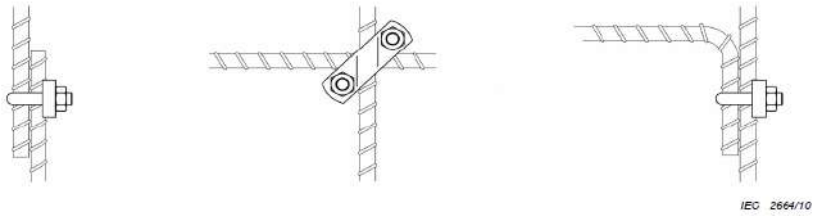


Figure E.5b – Clamped joints to IEC 62561 (suitable for lightning current and EMC purposes)

IEC 62305-3 Figure E.5 Typical methods of joining reinforcing rods in concrete

Joints of lightning conductors shall be clamp by IEC 62561-1 type-tested clamps, with the clamp material same or compatible with the down-conductor material per Table 5.

Joints of copper strips shall be tinned and bolted by means of exothermic welding or brazing. If there are overlapping joints, the length of the overlap shall not be less than 50mm to Figure E.5a under Section E.4.3.3 per IEC 62305-3. when it is necessary to bond the conductor to any metallic surface, it must be done by bolting, clamp or riveting. Particular care must be taken to ensure when attaching copper to any different material to prevent electrolytic corrosion. Proper bimetal connectors are to be used and connected properly. The LPS earth shall be bonded to the Main Earthing Bar with other earthing system in the structure.

Table E1 – Suggested Fixing Centres

Arrangement	Tape and Stranded Conductors (mm)	Round solid conductors (mm)
Horizontal conductors on horizontal surfaces	1,000	1,000
Horizontal conductors on vertical surfaces	500	1,000
Vertical conductors from the ground to 20m	1,000	1,000
Vertical conductors from 20m and thereafter	500	1,000

Note 1: This table does not apply to built-in type fixings, which may require special consideration.
Note 2: Assessment of environmental conditions (i.e expected wind load should be undertaken and fixing centres different from those recommended may be found to be necessary

1.10 Earth Electrode Chamber

Unless otherwise specified, every earth electrode shall be type-tested to IEC 62561-5. For earth electrodes located outside or on the apron of the building, earth inspection pit shall extend to a depth of not less than 300mm below finished ground level and kept free of soil. Each earth electrode pit shall be clearly marked 'LIGHTNING PROTECTION EARTH' and permanently fixed at the wall & connection of every down conductor to the earth chamber. Each earth electrode shall be copper steel rods with 16mm diameter and length of 1800mm with provision for screw coupling with another standard length. Each earth electrodes shall be driven 3000mm in depth. The connection of copper tape to earth electrode can be by exothermic welding or brazing.

The heavy duty chamber and cover shall be heavy duty design no less than 40kg/cm^2 to consider the traffic load at the location of installation. It should have a removable recessed cover to receive the architectural floor finish at the location of installation.

If the desired earth resistance cannot be reached after the first electrode is driven in the ground, then additional earth electrodes in parallel have to be installed outside the resistance area until required value is obtained.

1.11 Air Terminal Support

The Air Terminal Supports shall be tested to IEC 62561-4 for wall mounted type furnished with a maximum wind-load withstand capability. Material shall be within Table 5 & Table 6 requirements.

Air-terminals solutions taller than 1m height shall be furnished with a maximum permissible wind-load capability along with the proper installation guidelines to achieve that wind-load capability. Clamps that connect to the air-terminal to the conductors shall be subjected to IEC 62561-1 test requirements.

As a general rule, every sharp corner of the building roof shall have an air-terminal, unless protection volume if provided by a taller air-terminal using the rolling sphere method.

Protection Angle shall be per Table 2 of IEC 62305-1 and reference height shall be accordance to the item requiring protection from direct strike. Air-terminals placed at the edge of the building will have 2 different coverage angles based on 2 difference reference heights. Towards the roof, will have a more lenient angle, and towards outside the building will have a more acute angle due to reference height from ground level, if the angle protection method reaches its limits as stipulated in Table 2, then the protection volume method defaults to rolling sphere only.

The supporting mast shall be securely bolted to the structure on which it is mounted.

If the building exceeds 60m in height, the top 20% shall be protected from direct strike via exposed horizontal lightning conducting rings, horizontal air-terminals or natural air-terminals by handrail, facades or other metallic objects.

1.12 Earth Termination System

When dealing with the dispersion of the lightning current (high frequency behavior) into the ground, while minimizing any potentially dangerous overvoltages, the shape and dimension of the earth termination system are the important criteria. In general a low earthing resistance (if possible lower than 10 ohm when measured at low frequency) is recommended.

The down conductor connected to each earth termination shall have a resistance to earth not exceeding 10 ohms. The entire LPS shall have a combined earth resistance not exceeding 10 ohms.

1.13 Lightning Flash Counters

The lightning counter shall be outdoor type that triggers lightning strike. The lightning counter shall be installed above the test joint of the down conductor or any location as shown in the drawing at a height of 2500mm above the ground level.

1.14 Shop Drawings and As- built Drawings

The Electrical Contractor is required to prepare and submit shop drawings for the whole system before the actual installation work starts. If there are any amendments, the Electrical Contractor is required to resubmit the amended shop drawings after the return of commented shop drawings. The shop drawings should include all necessary details like layouts, positions and route of air termination system for the complete LPS installation. The cost of all the shop drawings are to be included in the Contract.

This include the As-Built drawings with details, certificated, documents, catalogues necessary for the completed building.

1.15 Test Certificate and Testing

All testing and measuring instruments used for testing the LPS installation must be tested and calibrated by certified test and calibration company for their accuracy and functionality. All Test and Calibration report results issued by the company must have a two (2) year validity period from the date of issuance.

1.16 Service and Maintenance of LPS

The Electrical Contractor is responsible for the service and maintenance of the completed installation during DLP. All works and cost shall be at the contractor expenses to rectify the defect due to installation faults. The contractor is required to include costs for maintenance during the maximum period between inspections of an LPS as shown below.

Protection level	Visual Inspection year	Complete inspection year	Critical situations [a] [d] Complete inspection year
I and II	1	2	1
III and IV	2	4	1

[a] Lightning Protection system utilized in applications involving structures with a risk caused by explosive materials should be visually inspected every 6 months. Electrical testing of the installation should be performed once a year.

An acceptable exception to the yearly test schedule would be to perform the tests on a 14 to 15 months cycle where it is considered beneficial to conduct earth resistance testing over different times of the year to get an indication of seasonal variations.

[d] Critical situations could include structures containing sensitive internal systems, office blocks, commercial buildings or places where a higher number of people may be present.

END OF SECTION

ELVC - LV CABLES AND BUSBAR TRUNKING

CONTENTS

ELVS - LV CABLES AND BUSBAR TRUNKING

1.0 GENERAL

1.1 Code and Standards

This section shall be designed and constructed in accordance with the latest revision of the following standards and the appropriate BS/IEC;

Standards	Document Titles
BS EN 60228:2005	Conductors of insulated cables
BS EN 60702-3:2016	Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V. Guidance for use
BS 6387:2013	Test method for resistance to fire of cables required to maintain circuit integrity under fire conditions
BS 5467:2016	Electric cables. Thermosetting insulated, armoured cables of rated voltages of 600/1000 V and 1900/3300 V for fixed installations.
IEC 60332 - 1	Tests on electric and optical fibre cables under fire conditions
IEC 61034-1	Measurement Of Smoke Density Of Electric Cables Burning Under Defined Conditions - Test Apparatus
BS EN 61034-2	Measurement of smoke density of cables burning under defined conditions. Part 2 : Test procedure and requirements
IEC 60331 : 2018	Specification for performance requirements for cables required to maintain circuit integrity under fire conditions
BS EN 13601:2013	Copper and copper alloys. Copper rod, bar and wire for general electrical purposes
BS EN 61439-2:2011: Part 1	Low-voltage switchgear and control gear assemblies. Power switchgear and control gear assemblies
BS EN 61439-6:2012: Part 2	Low-voltage switchgear and contro lgear assemblies. Busbar trunking systems (busways)
BS EN 60893-3-4:2004+A1:2012	Insulating materials. Industrial rigid laminated sheets based on thermosetting resins for electrical purposes. Specifications for individual materials. Requirements for rigid laminated sheets based on phenolic resins

1.2 Type Of Cables

All cables shall be manufactured to the relevant BS Standards. The conductors shall be high-conductivity, plain annealed copper conductors complying with BS 6360. The cables to be supplied suitable for a voltage of 600/1000V, unless otherwise specified, shall be of the following type, as indicated in the Drawings: -

a) For final sub circuits installed in conduit or trunking, cables shall be PVC insulated and manufactured to BS EN 60228:2005. For single phase circuits, the PVC cables shall be of 450/750V grade and for 3-phase circuits to 1000V grade.
b) For mineral insulated copper covered and PVC sheathed (MICC/PVC) cables or mineral insulated copper covered (MICC) cables, such cables shall be manufactured to BS EN 60702-3:2016 and certified to BS 6387:2013 - Class CWZ.
c) For PVC insulated steel wire armoured and PVC served overall (PVC/SWA/PVC) cables, such cables shall be manufactured to BS 5467:2016.
d) For cross-linked polyethylene insulated and PVC served overall (XLPE/PVC) cables, such cables shall be manufactured to BS 5467 : 2016 or IEC 60502.
e) For cross-linked polyethylene insulated, steel wire armoured and PVC served overall (XLPE/SWA/PVC) cables, such cables shall be manufactured to BS 5467 :2016 or IEC 60502.
f) Fire resistant cable to IEC 60331-21, IEC 60332 -1 and IEC 60332-3-22, -23, -24, IEC 61034, BS EN 61034-2, BS 6387:2013 Category CWZ., IEC 60754-1, -2
g) Flame Retardant cable to IEC 60332-1-2

The cables manufactured to the relevant BS Standards shall be taken as the minimum requirements except that the minimum insulation resistance at 20°C shall be 100 megaohms for 1000m of cable.

1.3 Submain Cabling

a) The submain cables and rising mains shall generally be run in trench, underground, trunking and cable tray. Where public areas are unavoidable, cablesshall be run within the false ceiling spaces. Minor alteration may be made to suit site conditions during the progress of work. The Contractor shall make allowancefor such alteration without any additional charge to the Client/Owner and carry outall necessary works to the satisfaction of the Consulting Engineer.

b) All incoming and outgoing feeder cables to each switchboard shall be provided with appropriate cable end-boxes and/or brass terminal glands and terminal blocksto suit the types and sizes of such cables as stated in the relevant specification and drawings forming part of this document.

c) Any parts found to be defective or, in the opinion of the Consulting Engineers incorrectly installed, shall be rejected and made good by the Contractor at his own expense. All power cable and control cables shall be provided with identification markers of permanent material and of approved type, at the termination of cable to enable the circuit to be traced with ease against a wiring diagram.

d) Minimum spacing between cables to be maintained as below:-

50mm	Between L.T. cables
50mm	Between Control cables
150mm	Between L.T. and control cables

1.4 Single Core, PVC Insulated Cables

The term "PVC insulated cable" shall mean a cable with polyvinyl chloride insulation.

a) Cables shall consist of copper conductors, pvc insulated to B.S.6004:2012 and the

corresponding Malaysian Standard MS 2112. Cable for three phases 1000 volt grade and single phase shall be 450/750 volt grade.

b) The current carrying capacity shall be in accordance with I.E.E. Regulation and shall be limited to the specified voltage drop and rating factor for ambient temperature specified.

c) All wiring shall be carried out on the loop-in system and enclosed in G.I. conduit or metal trunking. No joints or connectors will be allowed in any such cable except that connection may be used in accessible position within light fitting.

1.5 PVC Insulated, Steel Wire Armoured And Served Cables (PVC/SWA/PVC Cable)

a) All PVC/SWA/PVC cables shall be manufactured to MS 2101 and MS 2103 for voltage grades of 600/l000V.

b) The conductor shall be stranded of plain annealed copper with PVC insulation. The colour identification for the cores shall be as follows:

Twin Core	:	Red and Black
Three Core	:	Red, Yellow and Blue
Four Core	:	Red, Yellow, Blue and Black

c) The armouring shall be of single layer galvanized steel wires. The cable shall be served overall with a layer of extruded PVC. PVC/SWA/PVC cables shall be terminated by means of compression type of Alco make or its equivalent, constructed to grip both the inner and outer PVC sheath.

d) The minimum bending radius measured internally shall not be less than 12 times the outer diameter of the cable.

1.6 Mineral Insulated Copper Sheathed Cables

a) All mineral insulated copper sheathed cables (MICS) shall comply with B.S. 6207, Part 1:1969 and shall be heavy duty type. They shall be run and fixed on cable trays with clips and saddles. Saddles and clips shall be spaced not more than 1m interval.

b) Mineral insulated copper sheathed cables shall be supplied and installed strictly in accordance with the manufacturer's recommendations and instructions.

c) Cables shall be straight and run neatly. The bending radius shall be limited to 10 or 12 times the overall diameter of the cables. Every precaution shall be taken to ensure that no eddy current and circulating current will occur on the cable sheath. All single conductors shall be spaced adjacent to each other and run in trefoil formation.

d) Jointing and terminating of MICS cables shall be carried out using cold seals and all necessary short brass ring type universal glands.

e) Insulation and continuity test shall be carried out before and after MICS cable is

installed. The insulation resistance of a terminated cable should be greater than 100 megaohm when measured with a 500V or 1000V insulation tester immediately after sealing. This test should be repeated not less than 24 hours later. Any fault revealed in this test due to bad workmanship or faulty cable, shall be replaced at the expense of the Contractor.

f) It is absolutely essential that the greater care shall be taken to ensure those hands and all materials, particularly the compound, are perfectly dry and clean when terminating MICS cables. The length of tails shall be kept to the minimum. Dirt and metallic particles in the compound and any loose traces of dielectric left at the face of the sheath after stripping shall be carefully removed prior to sealing.

g) All MICS terminations shall be carried out using an earth- tail pot type seal to ensure effective bonding of non-current carrying metal work, including switch-boxes, to the copper sheath of the cable. Reliance shall not be placed on metalwork for earth continuity and separate copper connections shall be provided for this purpose.

h) The installation and termination of MICS cables shall only be carried out by experienced and registered competent wiremen recognized by the local Energy Commission (EC)./Suruhanjaya Tenaga.

1.7 Fire Resistant Cable

1.7.1 General description

Single-core single-insulated / Single-core double-insulated / Multicore / Multicore armoured power cable 0.6 /1 kV for fixed installation in cable systems with improved fire performance and circuit integrity. Flexible mineral insulation and sheathing, low smoke zero halogen (LSZH), non-toxic, for high temperature conditions and long expected life time. The cables shall fulfill high electrical and fire safety standards for indoor installation.

a) Construction

- Single core single insulated: Cu/MICA/XLPO-MI (LS0H) cross-linked
  - Conductor: Bare annealed copper, acc. to IEC 60228, class 2
  - Flame barrier: MICA tape
  - Insulation: mineral polyolefin-copolymer with content of minerals > 65%, electron-beam cross-linked, low smoke zero halogen (LS0H), highly flame retardant (min. LOI 38%)

- Single core double insulated: Cu/MICA/XLPO-MI (LS0H) cross-linked/ XLPO-MI (LS0H)
  - Conductor: Bare annealed copper, acc. to IEC 60228, class 2
  - Flame barrier: MICA tape
  - Insulation: mineral polyolefin-copolymer with content of minerals > 65%, electron-beam cross-linked, low smoke zero halogen (LS0H), highly flame retardant (min. LOI 36%)
  - Sheath: mineral polyolefin-copolymer with content of minerals > 65%, low smoke zero halogen (LS0H) , highly flame retardant (min. LOI 38%)

- Multicore: Cu/MICA/XLPO-MI (LS0H) cross-linked/GFT/ XLPO-MI (LS0H)
  - Conductor: Bare annealed copper, acc. to IEC 60228, class 2
  - Flame barrier: MICA tape
  - Insulation: mineral polyolefin-copolymer with content of minerals > 65%, electron-beam cross-linked, low smoke zero halogen (LS0H), highly flame retardant (min. LOI 36%)
  - Inner covering: Glass fiber tape (GFT)
  - Sheath: mineral polyolefin-copolymer with content of minerals > 65%, low smoke zero halogen (LS0H), highly flame retardant (min. LOI 38%)

- Multicore armoured: Cu/MICA/XLPO-MI (LS0H) cross-linked/GFT/ XLPO-MI (LS0H)/STA or SWA/ XLPO-MI (LS0H)
  - Conductor: Bare annealed copper, acc. to IEC 60228, class 2
  - Flame barrier: MICA tape
  - Insulation: mineral polyolefin-copolymer with content of minerals > 65%, electron-beam cross-linked, low smoke zero halogen (LS0H), highly flame retardant (min. LOI 36%)
  - Inner covering: Glass fiber tape (GFT)
  - Inner sheath: mineral polyolefin-copolymer with content of minerals > 65%, low smoke zero halogen (LS0H), highly flame retardant (min. LOI 36%)
  - Armouring: Steel tape (STA) or steel wire (SWA)
  - Outer sheath: mineral polyolefin-copolymer with content of minerals > 65%, low smoke zero halogen (LS0H), highly flame retardant (min. LOI 38%)

b) Electrical characteristics

- Rated voltage: U0/U = 600/1000V
- Test voltage: 4 kV / 50 Hz

c) Thermal characteristics

- For cables with the operating temperature 110°C:
  - Operating temperature: -30°C to +110°C
  - Laying temperature: -5°C to +70°C
  - Short circuit temperature: +280°C (5 seconds)

- For cables with the operating temperature operating 90°C:
  - Operating temperature: -30°C to +90°C
  - Laying temperature: -5°C to +70°C
  - Short circuit temperature: +250°C (5 seconds)

d) Cable and material properties

- Halogen free: IEC 60754-1
- Low corrosivity in case of fire: IEC 60754-2
- Low toxicity gases in case of fire: NES 02-713
- Low smoke density in case of fire: IEC 61034-1,-2
- Flame retardant of complete cable: IEC 60332-1-2

- For multicore/multicore armoured cables: Insulated conductors flame retardant acc. to IEC 60332-1-2
- No flame spread of bunched cables: IEC 60332-3-22, -23,-24 (Cat. A, B, C)
- Limiting Oxygen Index (LOI) for insulation and inner sheath material: ASTM D2863 ≥ 36
- Limiting Oxygen Index (LOI) for sheath material: ASTM D2863 ≥ 38
- Circuit integrity: IEC 60331-21 for 3 hours (180 minutes)
- Circuit integrity: BS 6387 C, with fire alone, temperature 950°C, 3 hours
- Circuit integrity: BS 6387 W, with fire and water spray, temperature 650°C, 30 min
- Circuit integrity: BS 6387 Z, with fire and mechanical shocks, temperature 950°C, 15 min
- Short-term aging tests for insulation material: IEC 60811-401, -501
  - Aging in air oven:
- Duration: 240 hours
- Temperature: 150±2°C
  - Tensile strength:
- Variation after aging: max. ±30%
  - Elongation at break:
- Variation after aging: max. ±30%
- Short-term aging tests sheathing material : IEC (EN) 60811-401,-501
  - Aging in air oven:
- Duration: 240 hours
- Temperature: 150±2°C
  - Tensile strength:
- Variation after aging: max. ±30%
  - Elongation at break:
- Variation after aging: max. ±30%
- Long-term aging tests insulation material: IEC 60216-1:2013
  - TI at 20'000 hours: > 116°C

e) Manufacturer's certification and factory surveillance

- OEM products are not allowed
- Quality and environmental control certificates of the manufacturer
  - ISO 9001
  - ISO 14001
  - OHSAS 18001
  - Regulation (EG) 1907/2006 (REACh) – manufacturer's declaration of conformity
  - EU directive 2011/65/EU (RoHS 2) – manufacturer's declaration of conformity
  - For railway projects: International Railway Industry Standard (IRIS)
- Product-specific third-party certification by:
  - LPCB (preferred), VDE, SEV, ÖVE
- Product-specific third-party surveillance of manufacturing by:
  - LPCB

2.0 BUSBAR TRUNKING SYSTEM

2.1 General

2.1.1 Work Description

This section specifies the supply, install, testing, commissioning and setting to work of a totally enclosed, non-ventilated type of housing low impedance insulated copper busbar trunking system.

Busbar trunking shall be of totally enclosed with independent copper earth bar, low impedance having minimum rating indicated in the Drawings and Specification with all necessary fittings, tap-off units, supporting system and manufacturer recommended accessories to complete the installation as a whole.

Ratings and the indicative routings of busbar trunking shall be as indicated on the Drawings. It is solely the responsibility of the Sub-Contractor to carry out site survey, co-ordinated and check the location of these facilities and make any necessary adjustment modifications to the Contractor or his representative's clearance.

2.1.2 Standards

The busbar trunking shall be low impedance solid rectangular busbars trunking made of totally enclosed galvanised steel sheet with electro-tin plated hard drawn high-conductivity copper to BS EN 13601:2013.

The busbar trunking shall be design verification (Design Verification Assembly) & Routine Verification as defined in BS EN 61439-2:2011: Part 1 (IEC61439-1), manufactured and tested by a specialist busbar trunking manufacturer to BS EN 61439-6:2012: Part 2 (IEC 61439 -2) or UL 857.

Material and installation shall comply with the Standards of ANSI, IEEE, ASTA, NEMA and UL. All components of the busbar trunking shall be listed.

The busbar trunking and associated equipment shall be certified for the category of duty specified hereafter, in particular, with regards to fault conditions and temperature rise limits. The manufacture of various components and accessories including the plug-in units, shall be as recommended by the busbar trunking manufacturer to ensure compatibility of the components.

2.1.3 Submission

All technical submission 'shall be accepted by the Consultant or his representative prior to the respective stages of construction.

As a minimum requirement the submission. shall include the following:

a) Equipment submission with manufacturer's data such a resistance per meter, reactance per meter, mV/A/m contact resistance per joint. etc.
b) Test certificate for short circuit capacity and IP rating;

c) Shop drawings for construction details of busbar trunking arrangements, spring hangers, wall flanges, floor flanges plug-in boxes, etc.
d) Busbar trunking routing drawings showing the co-ordinate routing of the busbar trunking, setting out lines of the busbar trunkings relative to building grids, locations of busbar trunking joints; suspension and fixing units, etc.
e) Weight of equipment
f) Builder's works requirement.

3.0 BUSBAR TRUNKING

3.1.1 General

Busbar trunking shall be factory fabricated epoxy insulated totally enclosed, vermin and insect proof, non-ventilated type suitable for three phase four wire system with full sized busbar for phases and neutral (100% neutral).

Busbar trunking complete with plug-in units shall be type-tested to ASTA (Association of Short-circuit Testing Authorities) certification, National Electrical Manufacturer's Association (NEMA) Standard and UL 857 and shall be able to withstand a short circuit condition equivalent to 50 kA 3 sec or not less than the type-tested short circuit capacity of the corresponding switchboards.

Busbar trunking shall be insulated to Class B i.e. 85°C temperature rise above ambient temperature of 40°C but maximum operation temperature should not exceed 95 ºC.

A complete busbar trunking assembly shall comprise the following:

a) Plug-in/feeder busbar
b) Plug-in/tap-off box
c) Cable tap box
d) Elbow and tee
e) Off set
f) Transposing unit
g) End cap/end closure
h) Flange end box
i) Hangers
j) Fire barrier
k) Expansion joints
l) Integral earth

Fire resistance busbar trunking shall be insulated with double layers of mica and silicone rubber on the busbars. All jointing parts shall be protected with fire protective enclosure. Test certificate for fire resistant busbar trunking shall be submitted to the Architect for clearance.

All busbar trunking and the associated fittings shall be minimum IP54 rating within Electrical room and riser at car park, outdoor or plant room areas shall be weatherproof type to IP 65 in accordance to IEC 60529. Weatherproof busbar trunking shall incorporate gaskets; drain holes, etc. suitable for outdoor use. All the plug-in, joint and accessories shall be special box-up to manufacturer detail to the same IP rating as the busway.

Minimum 2 nos. of hanger/support shall be provided for every 2m run of busbar trunking. Extra number of hangers will be required for joints. The busbar trunking shall be so supported that no visible stress shall be apparent from either unbalanced plug-in units. Vertical floor support shall be completed with spring hanger.

All joints shall be the one-bolt removable/isolating type with through bolts that can be checked for tightness without de- energizing the system. It shall be possible to make up a joint from one side in the event the busbar trunking is installed against the wall or ceiling. The joint shall be so designed so as to allow removal of any length without disturbing adjacent lengths. Belleville spring shall be provided to give positive pressure over complete contact area. Plug-in feeder shall use identical parts.

The busbar trunking system shall be capable of being mounted in any position without de-rating. Plug in and feeder sections shall be interchangeable without the use of special adapter joint covers.

The complete busbar trunking system. shall be capable or withstanding the short circuit capacity of the electrical installation without damaging by the electrical, mechanical and thermal stress under fault condition of a service voltage of 400V 50Hz.

Busbar trunking shall have rated insulation voltage and rated operating voltage of 690V respectively.

The busduct system shall be of the low impedance type, totally enclosed and non-ventilated for protection against mechanical damage and dust accumulation. The busduct system shall be manufactured and type-tested to IEC60529 (Classification of Degree of Protection) to meet the requirement of indoor and outdoor installation.

IP54	Indoor installation in non-sprinklered areas
IP65	Indoor installation in sprinklered areas
IP66	Outdoor installation

The busduct enclosure shall be rigidly constructed from electro-galvanized sheet steel of not less than 1.5mm in thickness and coated with epoxy powder paint to a black colour or the nearest manufacturer's colour of standard production. The assembly of the busduct enclosure shall consist of not more than two seams to enhance the mechanical strength of the busduct enclosure. The use of busduct enclosure as the earth conductor shall not be accepted.

The busduct system shall be capable of withstanding the short circuit strength (as indicated in the table below) of the electrical installation without damaging by the electrical, mechanical and thermal stress under fault condition. The short circuit rating of 1 second and 3 seconds shall be verified according to IEC 61439-2.

Busduct Rating	Short Circuit (kA/1sec)	Short Circuit (kA/3sec)	Busduct Rating	Short Circuit (kA/1sec)	Short Circuit (kA/3sec)
400A	20	11	2200A	85	50
600A	20	11	2500A	85	50
700A	35	19	3000A	120	70
800A	45	25	3500A	120	70

1000A	45	25	4000A	120	70
1250A	60	34	4500A	120	70
1600A	60	34	5000A	120	70
1800A	60	34	6300A	150	85
2000A	85	50			

1.2 Conductor

The copper conductors shall be three phases with full size neutral and half size integral earth made of hard drawn high conductivity solid copper bars to JIS H3140, ASTM B187M, BS EN 13601 and other relevant quality standards. Each conductor shall be round edge rectangular design and shall be electrically tin plated throughout its entire length.

Conductor shall be insulated over their entire length except at joints and plug-in contact positions. The insulation material shall be made of polyester film that meets the requirement of range -70ºC to 150ºC with the insulation voltage of 1000V. The integral earth bar (non-insulated) of half size of phase conductor shall be provided within the busduct enclosure.

The cross-sectional area (CSA) of copper conductors shall be in accordance to the following table as a minimum.

Busduct Rating	***CSA (mm^2)***
400A	120
600A	180
700A	240
800A	270
1000A	360
1250A	450
1600A	660
1800A	750
2000A	900
2200A	1050
2500A	1200
3000A	1320
3500A	1500
4000A	1800
4500A	2100
5000A	2400
6300A	3150

3.1.2 Busbar

Busbar shall be of hard drawn high conductivity tinned copper or adequate area complying IEC 61439. The maximum hot-spot temperature rise at any point in the busbar trunking at continuous rated load shall not exceed 55°C above a maximum ambient temperature of 40°C in any position.

Busbar shall be suitably plated at all joints and contact surfaces.

Busbar shall be tinned plated for low contact resistance.

Busbar support shall be supported by non-hygroscopic, non- flammable unbreakable and non-deteriorating polyester fibre insulator or insulator with characteristic similar to BS EN 60893-3-4:2004+A1:2012 at maximum 250 mm interval.

Busbar trunking system shall be terminated by end closure.

Unless otherwise highlighted, full size neutral of the same cross- sectional area as the phase conductor shall be provided for all rating of the busbar system. Refer to the drawing for double neutral size busduct as specified.

3.1.3 Housing

The housing shall be of extruded aluminium or electro-galvanized sheet steel with epoxy painted to provide maximum protection against mechanical damage, duct accumulation, and corrosion from water and other contaminants. All hardware shall be plated to prevent corrosion.

3.1.4 Plug-in

For vertical busbar risers, provisions shall be made in the trunking for tap-off units at intervals of 600mm; tap-off points where not used shall be provided proper outlet covers. Tap-off openings shall be of the safety type and in conjunction with the tap-off units shall have interlocks provided which prevent addition or removal of the tap-off unit when the switching mechanism is in the 'on' position. Metal parts of the tap-off units shall be designed to contact the metallic casing before the plug fingers contact the busbars. 'Danger' warning signs of an approved type shall be provided at all tap-off points. Feeder busbar trunkings utilised for the inter connection between transformers and the main switchboards shall not be provided with tap-off points.

When the busbar cover is opened, no live part can be accessed and the degree of protection provided shall have the same IP rating as specified for the busbar trunking

3.1.5 Plug-in unit (tap-off units)

Housing shall completely enclose the moulded case circuit breaker with rating as indicated in the Drawings. Enclosure shall be of galvanised sheet steel furnished in epoxy baked enamel paint over a rust inhibitor.

Stable shields shall be provided to protect stabs and ground plug body to busbar trunking housing before stabs make power contact. Earth terminal shall be provided inside plug body, adequate shielding shall be provided to prevent access to live parts when cover is open. An earth stab shall be designed to engage grounding tab on busbar trunking and internal earthing bus shall be provided.

Handle lock attachments complete with padlock and four keys shall be provided for padlocking cover and operating handle in either "ON" or "OFF" position. The operating handle shall be easily moved from end to side or vice versa so that it will be in the correct position to operate from the floor. All current carrying parts shall be suitably plated.

A releasable cover interlock shall be designed to prevent opening cover except when breaker is in "OFF" position. This interlock shall be convertible to non-releasable interlock preventing closing switch with cover open shall also be included, as well as an interlock to prevent insertion or removal from busbar trunking when in "ON" position.

Circuit breaker type plugs shall have an interrupting rating of not less than 36kA rms symmetrical and not less than the type tested short-circuit capacity of the designated bus bar trunking.

Plug assists shall be furnished on all plugs over 100A that will mechanically engage or disengage the plug from the busbar trunking, but only when the plug is in the "OFF" position.

3.1.6 Fire Barrier

All sections that passed through the floor slabs or walls shall have a minimum 2 hour rated (or rated not-less than that of the slab/wall) fire barrier in accordance to the requirements of the Local Authorities and local fire codes.

3.1.7 Expansion Joints and Transposition Joint

All busbar trunkings shall be equipped with expansion joints and also a transposition joint when it crosses a building expansion joint or to reduce the stress on the system by differential expansion. The busbar trunking expansion units shall be capable of taking up all thermal expansion due to the temperature differential of the busbar trunkings and building vertical settlement of not less than 100mm. Additional expansion units shall be provided along horizontal and vertical runs at intervals of about 30m, and where considered necessary by the busbar trunking manufacturer. This requirement is exempted if the manufacturer shall submit comprehensive calculation to warrant the expansion joints and transposition joints are not necessary.

3.1.8 Flange End / Flange End Box

Flange end or flange end box shall be provided for each busduct system. The rated current and rated short-time withstand current of the flange end shall not be less than that of the busduct system to which it is connected.

The removable bottom cover of flange end box shall be made of non-ferrous material for the ease of cable termination works.

Where connections are to be made to a switchboard or transformer, flange end shall be coordinated, such that the phase sequences at connected switchboard and transformer are matched.

Braided type of copper flexible link bar shall be connected between the transformer LV terminals and busduct flange end. Laminated type of flexible link bar shall not be acceptable.

3.1.9 Mounting Method

The full weight of the vertical busduct system shall be supported adequately by vertical spring hanger and vertical hanger which shall be mounted on the floor or wall. Intermediate supports shall be provided if the floor height exceeds 5000mm.

The horizontal busduct system shall be supported by horizontal hangers at every interval of 1500mm.

3.2 Busduct Joint Section

Busduct joints shall be of removable type with clamping bolts that can be checked for tightness without de-energizing the whole busduct length. It shall be possible to tighten a busduct joint from one side in the event of the busduct is installed against a wall or ceiling.

The joint shall be designed as to allow removal of any length without disturbing adjacent lengths. All bolts shall be tightened up by means of a torque wrench to a strength figure as recommended by the manufacturer.

The busduct joint shall be of the **double-bolt joint design** coupled with a pair of leaf springs to ensure constant pressure on the conductor contact areas.
In addition, the high tensile clamping bolts shall not penetrate through the conductors to ensure sufficient electrical contact and mechanical strength.

Bolt-through joint design and joint stack design shall not be acceptable.

The joint shall be covered up by metal cover plates of same type of material and finishes as the busduct enclosure.

4.0 Acceptance Tests at Manufacturer's Works

Completed busduct system shall be visually inspected for technical execution and conformity with the latest approved drawings and with the order. Spot checks shall be carried out to verify:

(1) Outline dimension of busduct enclosure

(2) The degree of protection of the enclosure

(3) Creepage distances and clearances

(4) Proper mounting of components

(5) Internal connections

(6) The availability of the earth points for connection

(7) Measurement of insulation resistance (Megger Test) on the conductors

(8) Dielectric test shall be carried out with 3.5kV rms for 1 minute

(9) Testing of the mechanical and electrical operation of a number of functional units on a random basis

5.0 Type Testing and Certification

KEMA type test certificates complying to IEC 61439-1 and IEC 61439-2 shall be submitted during the tender submission. The type test certificates shall include as follows:

(1) Verification of temperature-rise limits
(2) Verification of dielectric properties
(3) Verification of Short circuit strength
(4) Verification of Effectiveness of the protective circuit
(5) Verification of clearance and creepage distance
(6) Verification of degree of protection
(7) EMC test
(8) Verification of the resistance of insulating materials to abnormal heat and fire
(9) Verification of structural strength
(10) Verification of crushing resistance
(11) Verification of the electrical characteristics of the busbar trunking system
(12) Verification of resistance to flame propagation
(13) Verification of fire resistance to building penetration

END OF SECTION

EWIS - WIRING INSTALLATION SYSTEM

CONTENTS

EWIS - WIRING INSTALLATION SYSTEM

1.0 GENERAL

1.1 Wiring System

The wiring system shall consist of PVC insulated cables drawn into G.I conduits/PVC conduits and/or laid in trunking and cable tray.

1.2 Code and Standards

This section shall be designed and constructed in accordance with the latest revision of the following standards and the appropriate BS/IEC;

Standards	Document Titles
BS EN ISO 1461:2009	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods
BS 7371-12:2008	Coatings on metal fasteners. Requirements for imperial fasteners
BS EN 1562: 2019	Founding. Malleable cast irons
BS 7671:2018/A1:2020	Requirements for Electrical Installations. IET Wiring Regulations
BS EN 50085-2-1:2006+A1:2011	Cable trunking systems and cable ducting systems for electrical installations. Cable trunking systems and cable ducting systems intended for mounting on walls and ceilings
BS EN 10143: 2006	Continuously hot-dip coated steel sheet and strip. Tolerances on dimensions and shape
BS EN ISO 2081:2018	Metallic and other inorganic coatings. Electroplated coatings of zinc with supplementary treatments on iron or steel
BS 1449-1.14:1991	Steel plate, sheet and strip. Carbon and carbon-manganese plate, sheet and strip - Specification for hot rolled narrow strip supplied in a range of conditions for heat treatment and general engineering purposes
BS 1494-1:1991	Steel plate, sheet and strip. Carbon and carbon-manganese plate, sheet and strip - General specification
BS EN 60669-1:1999+A2:2018	Switches for household and similar fixed-electrical installations. General requirements
BS 1363	13 A plugs, socket-outlets, adaptors and connection units

2.0 CONDUITS

2.1 PVC Conduits

All rigid PVC conduit shall comply with the requirements of BS 6099 - Conduits for electrical installations. All conduit shall be of the high impact heavy mechanical strength type. Unless otherwise specified, all conduit shall be coloured white/black.

All conduit fittings shall comply with the requirements of BS 4607 - Non-metallic conduits and fittings for electrical installations. Conduit, fittings and accessories shall be from the same manufacturer.

No conduit smaller than 20 mm meter shall be used.

All conduit joints shall be made using a solvent adhesive recommended by the manufacturer of the conduit, to methods laid down by the manufacturer. All such joints shall be watertight. The same conditions apply to joints between conduit, fittings and accessories. Dipping of conduit or conduit fittings into solvent adhesives is forbidden. Before joints are made, conduit ends shall be cut square and all burrs and sharp edges shall be removed. Care shall be taken to remove all damp, grease, cement dust and oil from all faces of conduit and accessories prior to jointing. Conduits shall be entered fully into box spouts and butted into couplers, other than expansion couplers, for jointing purposes.

Screwed PVC conduit shall not be used unless specifically called for or when the PVC conduit is to be connected to metal equipment, conduit and fittings with screwed entries. Where such entries are not available, non-screwed male bushes and couplers shall be used.

Expansion couplers shall be used where straight runs of conduit exceed 8m. Within such couplers a space of not less than 10mm shall be allowed between the ends of the conduit. The solvent adhesive used in such joints shall allow for movement caused by expansion without affecting the water-tightness of the joint. A similar system shall be employed when conduits cross building expansion joints in any situation and the couplers shall span the joints.

All bends shall be made using the correct size spring. Conduit sizes of 25 mm and below may be set cold but all larger sizes shall be set hot. A pipe vice shall not be used during this or any other operation. The radius of any conduit bend shall not be used directly to heat conduit for bending purposes and the manufacturer's recommendation should be followed.

Full spacer bar saddles shall be PVC with bases. The fixing s shall be such that the conduits may be taken into accessories without sets or bends.

2.2 Conduits and Conduit Fittings

Conduits and conduit fittings shall comply with galvanized, heavy gauge, Class B, Screwed type complying into BS3 or BS4568, Class 4 protection against corrosion. The protective coatings on conduits and associated fittings shall be identical. No conduits having an outside diameter of less than 15mm shall be used.

Conduit boxes mounted outside a building shall have external fixing lugs. Boxes shall be of malleable cast iron and shall have a protective coating of zinc complying with BS EN ISO

1461:2009. Box covers shall have a machined surface around the perimeter mating with similar machined surface on the box. The cover fixing screws shall be of brass.

2.3 Adaptable Boxes

Adaptable boxes shall be of grey cast iron. Boxes mounted inside a building shall be of mild steel sheet.

The internal depth of a box shall be no less than 40mm and the thickness of its walls and base shall be as follows:

Grey cast iron - 2mm minimum
Steel sheet - 1mm minimum

Boxes of sheet shall have plain sides or be provided with 'knockout', and the corners shall be mechanically and electrically continuous.

Covers for boxes shall be of the same material and thickness as that of the boxes.

For boxes mounted outside a building, the covers shall have a machined surface around the perimeter mating with a similar machined surface on the box.

Covers shall be secured by a screw at each corner and by additional screws as necessary to provide a minimum spacing between adjacent screws, of 300mm for boxes inside a building and 150mm for boxes outside a building.

Fixing screws for covers shall be of brass, round or cheese head, size 2BA and shall engage not less than 4 full threads of the tapped hole in cast iron and 1.5 full threads in sheet steel.

Boxes mounted outside a building shall have external fixing lugs.

A box used with partitioned trunking shall have internal metal partition of the same material as the walls and base of the box. The thickness of the material used for the partitions shall be a minimum of 1mm.

The protective coating on boxes, covers, metal partition and associated conduits shall be identical.

2.4 Spacer Bar Saddles

The spacer bar saddles shall be of mild steel with bases of mild steel or malleable cast iron and shall be galvanised. Saddle bases shall be 3mm deep and may be solid or pressed from steel of not less than 1mm thick.

Saddle tops shall be fluted. The screw holes shall be of either slotted or keyhole pattern to permit the assembly and removal of the saddle top without removal of the retaining screws. Retaining screws shall be 2BA in size and be of brass or steel and zinc plated to comply with BS 7371-12:2008. Retaining screws shall engage not less than 1.5 full thread in bases pressed from steel.

2.5 Distance Saddle

Distance saddles shall be of malleable cast iron complying with BS EN 1562: 2012 and shall be hot-dip galvanised complying with BS EN ISO 1461: 2009. Bases pressed from mild steel shall not be accepted.

Saddle bases shall be of such depth that a nominal clearance of 6mm between the conduit and the wall or surface to which the saddles are fixed is provided.

Retaining screws for saddle tops shall be of brass complying with BS 7371-12: 2008.

2.6 Conduit Installation

Conduits shall run neatly on the surface or be buried within the carcass of the building or in the ground as shown in the Drawings.

Conduit run shall be determined by Contractor and agreed by The Contractor or his representative before any work is started. Conduit shall run at least 150mm clear of plumbing and mechanical services.

Conduit buried in concrete shall have 40mm depth of cover over its entire length. Conduit buried in plaster shall have 6mm depth of cover over its entire length.

Where conduit is buried in the carcass of a building or in the ground, all open ends shall be temporarily plugged to prevent ingress of foreign matter, moisture or water.

Where conduit buried in concrete crosses an expansion joint in the concrete, it shall be wrapped with waterproofing paper for a distance of 300mm on each side of the joint. Any alternative method shall be subject to the approval of the The Contractor or his representative.
Conduit shall be bent or set on Site to suit local conditions. Normal bends may be used with conduits of 40mm diameter and above.

Solid (non-inspection) conduit elbows or tees shall not be allowed.

A draw-in box shall be provided in all conduit runs exceeding 15m in length or containing more than two right angle bends.

Conduits shall be supported at regular intervals not exceeding 1.2m on horizontal runs and 1.5m on vertical runs.

Conduit boxes, both standard and adaptable shall be fixed to the structure of the building independently of the conduit.

The length of thread on the ends of the conduit shall suit the length of internal thread at the end of the fitting or accessory. Excess length of thread will not be permitted.

Spanners or purpose-made tool shall be used to tighten hexagonal bushes. Pliers and toothed wrenches shall not be used.

Conduit system erected outside a building shall be weatherproof.

Conduit terminating at boxes, trunking or accessories not provided with spout or tapped entries shall be made electrically continuous therewith by means of a flanged coupler and bush with male thread. Exposed conduit threads shall be given a coat of zinc rich paint.

Conduit buried in the ground shall be wrapped with PVC self-adhesive tape which shall be lapped at 50%. The taping shall extend for a distance of 150mm beyond the point where the conduit emerges from the ground.

The use of the conduit system itself as a means of earthing will not be permitted. A separate earth continuity conductor of appropriate cross-sectional area shall be used to run inside the conduit.

All conduits shall be painted with two (2) coats of an approved type of orange colour paint before erection. All scratches or paint work shall be touched up after installation. All conduits shall be provided with suitable draw-wires.

The number of cables pulled through any conduit shall be in accordance with BS 7671.

3.0 TRUNKING

3.1 Metal Cable Trunking and Fitting

Trunking and associated fittings mounted inside a building shall be of steel sheet complying with BS EN 50085-2-1:2006+A1:2011, Type 2, pregalvanized to BS EN 10143: 2006 and finished with a coat of approved paint, stove dried and hardened.

Trunking and fittings mounted outside a building or run in floor trenches subject to continued dampness or accidental flooding, shall be of continuously hot-dip galvanised plain steel sheet complying with BS EN 10143: 2006. They shall be weather-proof and shall be supplied in the 'as manufactured' condition. They shall have external fixing lugs.

Trunking and fittings shall have removable lids extending over their entire length. The lids shall be of the same material, thickness and finish as that of the trunking.

Metal partitions in trunking and fittings shall be provided as required by BS 7671. They shall be of the same material and finish as those of the trunking and shall be of a thickness of 0.5mm less than that of the trunking, subject to a minimum of 1mm.

Fixing screws for lids shall be 2BA in size and be of brass or cadmium-plated steel complying with BS 7371-12: 2008 and shall engage not less than 1.5 full threads of the tapped hole in the metal of the trunking or fittings.

3.2 Trunking

Trunking shall run neatly on the surface of the building and shall be truly vertical, horizontal or parallel with the features of the building.

Trunking runs shall be determined by Contractor and agreed by The Contractor or his representative before any work is started. Trunking shall run at least 150mm clear of plumbing and mechanical services.

Manufacturers' standard fittings shall be used. Only in cases where the standard fittings are unable to meet special local situations will fabricated fittings be accepted.

Where special fittings or sections of trunking are fabricated, they shall be prepared and finished to the same standard as the manufacturer's standard items.

Standard flanged couplings shall be used to terminate trunking at apparatus, at adaptable boxes and at points where it is required to connect one section of trunking to another where standard fitting is unwarranted. The practice of cutting and bending the material of the trunking to form flange attachment will not be accepted.

Connections between trunking and apparatus shall be by screwed coupler and bush, or a standard flanged coupling or an adaptor neck, fabricated or cast. Direct attachment of trunking to apparatus will only be permitted if cable entries are provided with smooth bore bushes or grommets and the return edge of the lid of the trunking is left intact.

Where connection is made between trunking and a distribution board, the cable entry or entries shall be sized to accept all cables from all used and 'spare' ways.
Holes in trunking shall be drilled, punched or cut by ring saw.

Individual pieces of trunking shall be independently supported. On straight runs, fixing shall be at regular intervals not exceeding 1.0m and fixing screws shall be of steel. Where weatherproof trunking is used, fixing screws shall be zinc plated (electro-galvanised) complying with BS 1706, Class B coatings.

The wiring capacity of conduits and trunking shall comply with IET Wiring Regulations.

Under no circumstances shall circuit cables from different distribution boards be run in the same trunking. Each circuit within the trunking shall be bound at regular intervals with cable ties for easy identification.

The trunking shall be manufactured from zinc-coated, mild steel sheet of 1.5mm for cross-section sizes up to and including 250mm by 100mm while 2.0mm sheet steel shall be used for cross-section sizes exceeding 250mm by 100mm.

A copper tape earth continuity conductor (25mm x 3mm) shall be provided throughout the trunking run and shall be bonded to the trunking at every section. In vertical runs, cable support pins and clips shall be fitted to support the weights of the cables.

4.0 PERFORATED CABLE TRAY

Perforated cable tray shall be supplied in standard lengths of 2.5m from plain steel, galvanised or precoated, complying with BS 1449: Part 1, Class 4 Protection. The cable tray shall be 1.5mm thickness for width of up to and including 200mm thickness and 2.0mm for width exceeding 200mm.

4.1 Bends

Bends shall be of the same material, thickness and finish as that of the cable tray and shall have an inner radius of 50mm and a straight length of 100mm at each end.

No perforation shall be made in the circular portion of 100mm and 150mm bends. On 225mm and 300mm bends, perforation shall be made only along lines set at 45^{o}. On 450mm and 600mm bends, perforations shall be made only along lines set at 30^{o} and 60^{o}.

4.2 Tees

Tees shall be of the same material, thickness and finish as that of the cable tray. The distance measured between a point of intersection and the end of the fitting shall be 100mm.

4.3 Fixing Screws

Mushroom-head steel roofing bolts and nuts complying with BS 1494: Part 1 shall be used to fix together adjacent sections of cable tray and/or accessories. Fixing screws shall be 6mm in diameter.

4.4 Installation Of Cable Trays, Accessories and Fixings

Cable tray shall only be cut along a line of plain metal and not through the perforations. All cut edges of galvanised cable trays shall be prepared and treated with zinc rich paint.

Cable tray routes shall be determined by Contractor and agreed by all parties representative before any work is started.

Site fabrication of cable trays shall be kept to a minimum and manufacturers' standard items shall be used. Where special sections are required, the material, thickness and finish shall be as specified for standard items.

Where welding has been employed in the fabrication of cable trays and/or accessories, the area around the joint shall be mechanically prepared and thereafter treated with zinc chromate primer or zinc rich paint according to the original finish of the metal.

Fixing for cable trays shall be disposed at regular intervals not exceeding 1.2m at 225mm from bends and intersections.

Fixing shall be fabricated from mild steel flat bar complying with BS 1494 and shall be hot-dip galvanised to comply with BS EN ISO 1461: 2009.

5.0 WIRING ACCESSORIES

5.1 Switches

Switches shall be installed such that the operating dolly shall be pushed up for “off” and down for “on”.

Single pole switches shall be connected to break the phase wire of the supply. The neutral wire shall not be routed through switchboxes.

Switches to BS EN 60669-1:1999+A2:2008 with steel cover plates of approved finish shall be installed. These switches shall be the grid type with 15 amp dolly operated switches, single or multi-gang, one, two or intermediate way.

Earthing terminal connected to the earth continuity terminal shall be provided and connected to the earth continuity conductor at every lighting switch position.

Switches shall be suitable for use on inductive or resistive loads. They shall be flush type, ivory coloured and rocker operated. For exposed conduit wiring, the switches shall be metalclad. Switches shall be rated at 5 amperes or 20 amperes as required by the circuit duty.

Switches for lighting shall be mounted at a height of 1.3 metres above finished floor level and where mounted adjacent one to another, they shall be grouped in a single enclose (multi-gang box) and share a common switchplate.

5.2 Switch Socket Outlets

Switch socket outlets shall be 13 amperes, shuttered 2 pole and earthing pin type and shall comply with BS 1363. Unless otherwise indicated, they shall be flush type, ivory coloured with single pole rocker switch.

For concealed wiring, they shall be mounted 300mm above the finished floor level. For exposed conduit wiring, the switch socket outlets shall be metalclad.

5.3 Switch Boxes and Socket Outlet Boxes

For concealed wiring, the boxes used for mounting switch plates and sockets shall be metalclad type with one (or both) insulated sliding lugs. The sliding lugs shall be used for adjusting squaring errors when mounting the switch plates and socket outlets. Switch plates and socket outlets shall be fixed to the boxes by means of flatbase chrome screws.

5.4 Cord Operated Switches

A minimum length of 1.5m operating cord shall be provided unless otherwise indicated. The colour of operating cords shall be white or natural and the free end shall be terminated in a moulding of rubber or plastic material.

5.5 Switch with Pilot Lamp

The pilot lamp shall be a neon/LED lamp with resistor and red coloured lens unless otherwise indicated.

5.6 Ceiling Fans

Ceiling fans shall be 1524mm sweep model fitted with capacitor type motor suitable for operation on 230V 50Hz AC single-phase and supplied complete with down rods to suit mounting heights and speed regulators. The fans and regulators shall be of the type approved by Suruhanjaya Tenaga and SIRIM.

5.7 Wall Fans

Wall fans shall be 26 inch industrial type model fitted with capacitor type motor suitable for operation on 230V 50Hz single phase. The wall fans shall be capable of being poised at 15^{o} above and 45^{o} below the horizontal. The fans shall be capable of oscillating with an angular of

120° in the vertical plane. The fans shall be of the type approved by Suruhanjaya Tenaga and SIRIM.

5.8 Hand Dryers

The hand dryers shall be of the type approved by the Suruhanjaya Tenaga and SIRIM. The units shall operate from a 230V mains supply and shall not exceed 2 kW rating.

The hand dryers shall be made from sheet steel and finished in white enamel. No plastic shall be used. The unit shall be suitable for wall mounting.

The hand dryers shall make use of warm circulating air for drying. The unit shall have a sensor switch with a built-in time mechanism which switches the unit off automatically after approximately 40 seconds.

The motor shall be brush-free with permanent lubrication and ball bearings.

The hand dryers shall have clear concise instruction for use on the unit.

Contractor shall prior to placing his firm order with his supplier for the hand dryers provide a sample for approval by the Client and Consultant.

6.0 APPLICATION OF PAINTING

All parts of the work installed under this Contract shall be painted with approved first quality enamel paints, except those items specified as being painted by the Contractor or otherwise exempted from painting in this section of the Specification.

Generally, all services exposed to view and inside plantrooms shall be provided with colour paint finish.

The requirement for painting of all pipework and ductwork is in addition to the colour coding or banding specified in this Specification.

Paint shall be selected to withstand the temperature on the surface which it is applied, and shall be suitable in all respects for the environmental conditions in which it shall be located.

All metal work exposed to atmosphere e.g. roof mounted plant shall be epoxy to withstand the effects of chemical attack as experienced in areas close to cooling towers and sea front.

All paint used shall be of one approved manufacturer, and finishes shall be full gloss unless otherwise specified.

Before ordering any primer, undercoat and finishing paint, the Contractor shall propose the colour scheme with painted colour sample to the approval of the Architect.

Before ordering any painting materials, the Contractor shall obtain from the Architect the type and manufacturer of all materials.

The Contractor shall select all finishing and painting materials from types suitable for the surfaces to which they are applied and for the environmental conditions in each area.

Table 1

Item	Colour
Switchboard	Grey
Control Panels	Grey
Electrical Motor Primrose	Black
Electrical Installation (Electrical Conduit, Power and Lighting Points)	Orange (Tango)

Colour scheme proposed by the Contractor shall be made reference to a recognised international standard acceptable to the Architect.

All expose series pass through public access area shall be finishes with colour matching surrounding with colour Band Identification as above.

All colour Identification shall comply with local Authority and JBPM requirement.

END OF SECTION

ELFL - LIGHT FITTINGS AND LAMPS

CONTENTS

ELFL - LIGHT FITTINGS AND LAMPS

1.0 GENERAL

The light fittings shall be selected on the basis of minimum owning cost, with particular emphasis on energy efficiency and maintenance requirements. All lighting fittings shall be suitable for the Site ambient temperatures and humidity and shall be suitable for working at these temperatures with due allowance for local heating both within the fitting and for local ambient temperatures.

The materials and finishes of light fittings shall comply with BS EN 60598-1:2015. All outdoor fittings shall be weatherproof (IP65). Fittings and control gear in outdoor locations shall be designed to withstand without failure or deterioration the metal temperatures reached due to continuous exposure to direct sunlight and shall be weatherproof. The lamp fitting at battery room shall be corrosive resistance. All lighting at areas prone to vandalism shall be inclusive of protection cover..

Brass earthing screws with spider washers shall be provided for earthing the fittings.

Lamp holders shall be bi-pin, spring loaded, designed to retain positively the lamp caps independently of the contact spring and of robust construction complying with BS EN 60061-1:1993+A53:2015, BS EN 60061-2: 1993+A53:2015 and BS EN 60061-3:1993+A53:2015.

1.1 Code and Standards

This section shall be designed and constructed in accordance with the latest revision of the following standards and the appropriate BS/IEC;

Standards	Document Titles
BS EN 60061-1:1993+A57:2018	Lamp caps and holders together with gauges for the control of interchangeability and safety. Lamp caps
BS EN 60061-2: 1993+A54:2018	Lamp caps and holders together with gauges for the control of interchangeability and safety. Lamp holders
BS EN 60061-3:1993+A55:2018	Lamp caps and holders together with gauges for the control of interchangeability and safety. Gauges
IEC 61347-2-13	Lamp control gear - Part 2-13: Particular requirements for d.c. or a.c. supplied electronic control gear for LED modules
IEC 61000	Electromagnetic compatibility
BS EN 55015:2013+A1:2015	Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment
BS EN 12464-1: 2021	Light and lighting. Lighting of work places. Indoor work places
IEC 62262	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
BS 7430: 2011 +A1 :2015	Code of Practice for Protective Earthing of Electrical Installation
BS EN 60432-1:2000+A2:2012	Incandescent lamps. Safety specifications. Tungsten filament lamps for domestic and similar general lighting purposes
BS EN 60188	High-pressure mercury vapour lamps - performance specifications

BS EN 60238:2018+A2:2021	Edison screw lampholders
BS EN 60529:1992+A2:2013	Degrees of protection provided by enclosures (IP code)
BS EN 60309	Plugs, socket-outlets and couplers for industrial purposes. Dimensional interchangeability requirements for pin and contact-tube accessories of harmonized configurations
BS 5733	Specification for general requirements for electrical accessories
BS EN 60670-1:2005+A1:2013	Boxes and enclosures for electrical accessories for household and similar fixed electrical installations. General requirements
BS 1362	Specification for general purpose fuse links for domestic and similar purposes (primarily for use in plugs)
BS EN 60947-3 : 2019 +A2:2015	Low-voltage switchgear and control gear. Switches, disconnectors, switch-disconnectors and fuse-combination units
MS 983	2004 'KELUAR' Signs (Internally Illuminated) – Specifications
MS 619-2-22	2005 Luminaires – Part 2-22 Particular requirements for emergency lighting
IEC 60629 / BS EN 60529	Specification for degrees of protection provided by enclosures (IP code).
MS IEC 60838-2-2:2008	Miscellaneous Lamp Holder – Part 2-2: Particular requirements – Connectors for LED Modules
MS IEC 61347-1:2012	Lamp Control Gear – Part 1: General and Safety Requirements
MS IEC 62031:2011	LED Modules for General Lighting – Safety Specifications
MS IEC 62384:2012	DC or AC Supplied Electronic Control Gear For LED Modules – Performance Requirements
MS IEC 62560:2012	Self-Ballasted LED Lamps for General Lighting Services by Voltage >50V – Safety Specifications
MS 62504:2012	General Lighting – LEDs and LED Modules – Terms and Definitions
MS 62612:2012	Self-Ballasted LED Lamps for General Lighting Services – Performance Requirements
MS 62717:2014	LED Modules for General Lighting –Performance Requirements
MS 62722-1:2014-9	Luminaire Performance – Part 1: General Requirements
MS 62722-2-1:2014-11	Luminaire Performance – Part 2-1: Particular Requirements for LED Luminaires

All lighting fittings shall comply with MS IEC 60598-1"Specification for general requirements and tests"

All lighting fittings shall be supplied complete with lamps and control gear and shall be effectively earthed in accordance with BS 7671 "Requirements for electrical installation - IEE Wiring Regulations, the latest Edition". The general, safety and performance requirement of ballasts for discharge lamps shall comply with MS IEC 60923 "Performance requirements for lamps-ballasts for discharge lamps performance requirements" and MS IEC 61347-2-9 "General and safety requirements for ballasts for discharge lamp" respectively.

2.0 LIGHTINGS AND LAMPS

2.1 LED Light Fittings

The proposed LED lighting fittings shall be environmental friendly and free of mercury. For each type of lighting fixture, data on features, accessories, finishes and the following shall be included:

a) Physical description of lighting fixture including dimensions.

b) Details of driver(s) including driver efficiency, catalogue code and input watts.

c) Luminaire photometric reports.

d) Luminaire coefficient of utilization data for reflectance values of 0/0/0.

e) Table of zonal lumen output in 100 vertical increments showing both the lumen value and the percentage of total output per 100 increments.

f) Initial lumen, output of light source and temperature at which the lumens are rated.

g) Design lumen output of light source and percentage of rated life which design value is derived.

h) Correlated Colour Temperature (CCT) of light source and percentage of rate life in which design value is derived.

i) Colour-rendering Index (CRI) of light source.

j) Computer calculation or simulation for the relevant area.

k) Calculations of energy used to light up one unit of task area to the required level.

l) Relevant test certification.

m) Detailed installation method.

n) Detailed accessories list and technical catalogue.

LED sources within the fixtures shall meet the following requirements:

a) Operating temperature rating shall be between -40°C and +50°C

b) Correlated colour temperature (CCT): 4000K ± 300K

c) Colour rendering index (CRI) shall depends on area or location as follows:-

   (i) Car parks, corridor, staircases , general areas : 80

d) Luminaire manufacturer shall submit reliability reports indicating that the manufacturer of the LED (chip, diode, or package) has performed JEDEC (Joint Electron Devices Engineering Council) reliability tests on the LEDs as follows:

   (i) High temperature operating life (HTOL)

(ii) Room temperature operating life (RTOL)
(iii) Low temperature operating life (LTOL)
(iv) Powered temperature cycle (PMTCL)
(v) Non operating thermal shock (TMSK)
(vi) Mechanical shock
(vii) Variable vibration frequency
(viii) Solar head resistance (SHR)

e) Certification of IESNA LM80 test

The fittings shall operate on 220-240V mains voltage with a power driver complying with IEC 61347-2-13. The LED driver(s) shall meet the following requirements:

a) Drivers at maximum load shall have a minimum efficiency of 85%

b) Operating temperature -40°C to +50°C

c) The drivers shall be of constant current of not more than 700mA for optimal LED efficiency and maximum life time of equipment.

d) Power supplies shall be UL Class 1 or II output.

e) Surge protection testing certification to IEC 61000. For luminaires without external surge protection device, the luminaries shall have protection against unpredictable power surges up to 10kV.

f) Drivers at maximum load shall have a power factor (PF) of ≥ 0.90

g) Drivers at maximum load shall have a Total Harmonic Distortion (THD) of ≤ 20%

h) Electromagnetic Interference (EMI) of drivers shall comply with BS EN 55015:2013+A1:2015 and IEC 61000.

The luminaries shall be easy to maintain and able to maintain 70% of its initial luminous flux (L70) after 50,000 hours of operation in an ambient temperature and operating current used in this project. Manufacturer shall provide lumen maintenance life projection based on IES TM-21. A maintenance factor of 0.8 shall be used in calculating the illuminance value. Unified Glare Ratio (UGR) and reference surfaces of the luminaries shall comply with BS EN 12464-1. UGR for work areas in stations shall generally be 19 to 28.

The Consultant/Client or his representative may request for an independent testing of sample luminaries to verify luminaries' performance and compliance with the specifications. Testing shall be conducted as per applicable Malaysian Standard and any other equivalent standards. The Consultant or his representative shall judge regarding acceptability of the optical system's performance. The Consultant or his representative may request for factory inspections. Factory inspections shall be arranged by the manufacturer prior to the delivery of the material.

Details of the lighting control system to be provided as part of the works have been included in the drawings provided for information purposes, and the Sub-Contractor shall utilize the provisions as far as possible. The Sub-Contractor shall note that the proposed LED fittings specifications as shown in the drawings provided for information are indicative only and the actual quantity, location and power

consumption shall be proposed and designed in compliance with the necessary illuminance level. Any additional conduits, components, cables and necessary accessories required for the lighting control system shall be provided by the Sub-Contractor and coordinate with the Sub-Contractor's nominated Sub-Contractor for the station lighting works.

The type of LED luminaries at public area shall be proposed to adapt the ceiling finishes and comply with all the above mentioned requirements. Suitable LED luminaires shall be provided to illuminate areas. Type of fittings to be used shall be as follows:

a) Recessed or suspended modular linear LED luminaire with high purity aluminium housing, high strength frosted polycarbonate/acrylic diffuser, vacuum coating reflector and high efficiency driver.

b) LED based recessed down light with high strength frosted polycarbonate/acrylic diffuser, high purity aluminium housing, vacuum coating reflector and high efficiency driver.

The LED luminaries and its associated electrical components shall comply with the following specifications: -

c) Tested to optical and compartment gear tightness as per below:

Location	**IP Rating**
Entrance	IP 65
Landscape	IP 65
Street Lighting	IP65

d) Shall be robustly constructed from aluminium alloy with a flat, high strength frosted polycarbonate/acrylic diffuser of impact resistant IK07 to IEC 62262.

e) Shall be equipped with LED photometric engines composed of modular quantities of high power LEDs.

f) Each LED shall be associated with specific lens that generates the required photometric distribution of the luminaries. In the case where reflector system is used, the reflector shall be made of high purity anodised aluminium.

g) Where necessary, the recessed modular linear LED luminaire shall be designed to be integrated into an extruded aluminium profile (boom box).

h) The luminaries shall be attached to the boom box by a hinge system which in the opened position provides access to the cable tray and the junction box housing the power supply or driver.

i) For public area, Energy saving LED lighting fittings with harmonic filtering shall be provided. Down lights shall be considered for aesthetic purpose to complement architectural finishes, where appropriate. The light fitting shall be easily accessible for maintenance. Shading designs, lighting levels and type shall be guided by the table below and comply with MS1525:2007 or other Regulatory requirement.

Public Areas in Stations	Lux	Reference Plane
Entrance/Concourse - general area	200	1 m (Above Finish Floor Level)
Barrier gate area	200	1 m (Above Finish Floor Level)
Car Park	200	1 m (Above Finish Floor Level)
MDF/SDF/Electrical Plant Room	200	Above Finish Floor Level
Escalators	200	Treads
Stairways	200	Treads
Stairways (Enclosed)	200	Treads
Passageways	200	1 m (Above Finish Floor Level)
Exits of streets	200	Above Finish Floor Level
Entrance general area	200	Above Finish Floor Level
Offices /Retail Lots Rooms	400	Work Level
Fire Operations Control Rooms	400	Work Level
Staff Locker Rooms/Toilets/Surau	150	1 m (Above Finish Floor Level)
Store Room/Electrical Riser Room	150	1 m (Above Finish Floor Level)
Plant and Equipment Room	200	1 m (Above Finish Floor Level)

Table 1 Lighting Criteria

j) Roof soffit for façade architectural LED lighting shall be provided as per the drawings of the relevant Contract. The roof facade lighting shall be weatherproof for outdoor installation with an IP65 level. The Sub-Contractor shall allow for the mounting of the roof facade lighting (using up lighter) at the platform level. The Sub-Contractor may propose to mount the roof facade architectural lighting on columns, the floor slab above plant rooms, and roof structure, as shown in the Contract.

The facade architectural lighting shall be able to enhance the outlook of the stations during the night with the effects of beam spotlights and/or softly washed lights to enable passengers within a distance of 50m away to identify the stations. Control for this lighting shall be included as part of the Works. The control features shall be flexible and adjustable to suit the required station's facade. The lighting shall be dimmable and have colour changing capability with a minimum of 10 colours including yellow, blue, purple, green, amber and red. The control features shall include colour changing duration of one hour for each colour (duration of colour change shall be adjustable) with a minimum of 4 zones.

The lighting Sub-Contractor shall submit computer generated imagery of the stations in accordance with the Specifications as part of his proposals for the facade architectural lighting. The glazing selection and shading design of the façade shall form a system that effectively avoid excessive heat transmission, helps the use of natural daylighting deep into the building and satisfies tenant comfort with glare protection. The daylight factor of a typical office space shall not fall below 1.0% in line of 5 meters from façade.

2.2 Lamps and Tubes

Sub-Contractor shall supply all necessary lamps for the lighting fittings.

All fluorescent tubes shall be of the energy saving type with bi-pin caps and maximum 40 watts. Tubes used shall be cool white (Day light) with color temperature 4100K. Tubes for Power Sub Station like LV room, switchgears room and other shall be Tropical Daylight with color temperature 6500K. The lumens output for the cool white tubes after 100 hours of burning, shall not be less than 3250 lumens for the 36 watts tube and 1300 lumens for the 18 watts tube and shall have an average life-span of 7,500 hours.

Incandescent lamps shall be of pattern E27 in IEC 64 (Edison Screw) pearl, gas filled tungsten type up to 100 watts. It shall have an average life span of 1000 hours.

Metal halide lamps shall comply with IEC 188 and shall have pattern E40 of IEC 64 (Goliath Edison Screw). The lamps shall have a luminous efficiency of not less than 63 lumens per watt and shall have an average life span of 6,000 hours.

2.2 Installation of Fluorescent Light Fittings

All internal wiring for fluorescent lights shall be neatly arranged and taped with intermediate terminals provided with external connection. Brass earthing screws with spider washers shall be provided for earthing the fittings. All installation shall follow as per BS 7430: 2011–Code of Practice for Protective Earthing of Electrical Installation.

The cutting of down rods or the provision of extended down rods to suit mounting height shall be undertaken. Where fluorescent light fittings are to be installed on the underside of the ceilings, suitable spacers that shall be inserted between the top of the fittings and the underside of the ceiling in such a manner as to allow a minimum clearance of 12mm.

All fluorescent light fittings shall be secured with metal threaded studs complete with washers, two lock nuts using cartridge hammer or similar apparatus. The threaded metal studs shall penetrate in hard concrete to a depth not less than 32mm.

For recessed fluorescent fittings in suspended ceilings, the fittings shall be suspended from similar threaded studs using 18 SWG steel wire, to prevent additional weight and sag to the suspended ceiling. Sub-Contractor shall install a mock-up ceiling complete with fittings, for The Consultant/Client or his representative approval.

2.3 Sample of Light Fittings

Sub-Contractor shall, prior to placing his firm order with his supplier for light fittings, provide two (2) samples of each light fitting for verification and approval by The Contractor or his representative.

2.4 LED Self Contained Emergency Lights

Self-contained emergency light fittings of the LED approved by the Jabatan Bomba dan Penyelamat Malaysia and complying with MS 619 shall be supplied and installed as shown in the Drawings. Acceptance certificate from Jabatan Bomba dan Penyelamat Malaysia shall be submitted.

The emergency light fittings shall be a `non- maintained' type i.e. the lamp is off as long as mains supply is on, and the same lamp is illuminated from a nickel cadmium battery when the mains supply is interrupted.

The emergency light fittings shall be provided with sealed nickel cadmium batteries having a minimum capacity capable of maintaining the units in full illumination for a period of at least 3 hours when the mains supply is interrupted. An automatic charger unit which shall maintain the battery in a fully charged condition shall also be incorporated within each unit. The unit should allow for easy and simple replacement of batteries in its design.

The units shall also be provided with long life LED mains failure and charger on indications as well as a mains failure simulation press button test switch. An internal switch shall be provided to disconnect the lamps when required.

2.5 LED Keluar Sign

`KELUAR' sign light fittings of LED type approved by the Jabatan Bomba dan Penyelamat Malaysia and complying with MS 983 shall be supplied and installed as shown in the Drawings. Acceptance certificate from the Jabatan Bomba dan Penyelamat Malaysia shall be submitted.

The `KELUAR' sign light fitting shall be a self-maintained unit i.e. the lamp shall be continuously lit from normal mains supply and upon mains failure powered by a sealed nickel cadmium battery. The illumination level shall be uniform throughout the sign fitting and with sufficient downward illumination.

The word `KELUAR' shall be in letters 150mm high, 75mm wide and 19mm wide strokes. The lettering shall be illuminated red against black background or white against green background to the The Contractor or his representative requirement's `KELUAR' signs light fitting shall be the following types: -

a) Single sided signs with the lettering `KELUAR' with or without directional arrows to the The Contractor or his representative requirement

b) Double sided sign with the lettering `KELUAR' with or without directional arrows to the The Contractor or his representative requirement

The `KELUAR' sign light fittings shall be provided with sealed nickel cadmium batteries having a minimum capacity capable of maintaining the units in full illumination for a period of at least 3 hours when the mains supply is interrupted. An automatic charger unit which maintains the battery in a fully charged condition shall also be incorporated within each unit.

The batteries should be held firm in position by a snap on stainless steel clip so that the batteries may be replaced simply. Screw type connectors should be provided to enable disconnection of the batteries.

The units shall also be provided with long life LED "mains failure" and "charger on" indications as well as a mains failure simulation push button test switch. An internal switch shall be provided to disconnect the lamps when required.

2.6 LED Downlight

Downlight fittings shall in general be similar to the type shown in the Drawing. Reflectors shall be of aluminium material and shall be sand blast treated or highly polished as required by the Contractor or his representative. The final selection of the reflector colour and trim colour shall be by the Consultant/Client. The Contractor or his representative requirement without any additional variation claim by the Sub-Contractor. The Sub-Contractor shall be responsible for the coordination involving all services in the ceiling in particular, in term of cut out holes for the downlight and eyeball fittings, recessed depth of the fittings etc.

All downlight and eyeball light fittings shall be completed with lamps, control gears and mounting brackets. All mounting brackets shall be factory manufactured. Paintings of all parts of the light fittings shall be done in the factory of the light fitting manufacturer.

Incandescent lamps shall comply with BS EN 60432-1:2000+A2:2012 with type and rating as indicated. They shall be coiled filament type up to 100W with a normal life of 1000 burning hours.

2.7 Flood light

The floodlight specification shall be at least 50 watt and clear tubular type. The lamp holder and sealing ring shall be corrosive resistant, weatherproof and withstand with direct exposure to sunlight.

2.8 Wall Light

The wall light fitting shall be supplied complete with lamp, lamp holders and completely wire and fully tested to ensure reliable performance and quality.

The housing and reflector shall be recessed type, die-cast aluminum and sealed to IP65. They shall be specially treated to prevent rust and corrosion. The unit shall be suitable for wall mounted and the front glass shall be asymmetric with grille.

2.9 High bay-light fitting

All highbay light fittings shall in general comply with BS EN 60188. The light fittings shall be equipped with mounting ring for rod/conduit suspension. There shall be one cable entry with an outside pipe thread in the light fitting ceiling and another cable entry at the side for connection to a 3-terminal connector.

The light fitting housing shall be of hot-dipped galvanized or epoxy coated sheet steel and be properly ventilated for controlled cooling of the auxiliary gear. The reflector shall be have anodized pure aluminium. The light fitting shall be complete with all necessary accessories.

Discharge lamps shall be of the Edison screw type and shall comply with the requirements of BS EN 60188. The lamp holders shall comply with the BS EN 60238:2004+A2:2011. All discharge lamps shall have bodies formed from porcelain or like material guaranteed not to deteriorate under the temperatures encountered in service.

Power factor correction capacitor to correct power factor to 0.90 or better shall be provided. Such capacitors shall comply with BS EN ISO 60188.

2.10 Lighting Fittings

All lighting fittings shall be supplied complete with lamps (as specified in drawings) and all necessary control gear fully wired and fixed. The gear shall be integral with the lighting fittings. The lighting fittings wiring shall be sized and insulated with materials that will effectively withstand the current, voltage and temperatures expected within the lighting fittings during both the starting and operating modes in the ambient temperatures of the Site.

The lighting fittings shall provide the requisite light distribution with size and type of lamp specified. Any adjustments required to accommodate any alternative lamp sizes shall be positive and lockable in the final position.
All lighting fittings shall be totally enclosed, dust proof, insect proof and water tight. The degree of tightness shall be as a minimum IP65.

The lighting fittings should be made from high quality 3mm thick corrosion resistant aluminium alloy with a smooth and anodized finish. Side covers should be made of die-cast aluminium alloy and fixed to the body. End plate joints shall be continuously welded to maintain strength and integrity of fitting.

The lamp compartment shall be accessible via a continuous toggle secured toughened front glass assembly (cover). The glass shall be of minimum 5mm thickness. The continuous toggle shall ensure even and consistent closure of the front covers to the lighting fitting.

In the close position, the front cover shall be firmly upon soft resilient gasket made of silicone to ensure compliance to IP65. In the open position, the front cover shall be restrained from becoming detached or blown against the other parts of the lighting fitting. Rapid access to lamp and control gear should be made simple and should not require the use of any tools, using quick stainless steel catches. A separate control gear plate in the integral in the lighting fitting should be provided for mounting of control gears. A quick disconnecting plug shall be provided for safety and ease of maintenance.

2.11 Small Power

13A socket outlets shall be connected in a ring or radial system in accordance with BS 7671 or shall be spur feeds. All 13A socket outlets shall be shuttered type, comply with MS 589 -1&2, except two pole and earth flat pin plugs and have switches with a rocker type lever. The front plate of the socket outlets shall be polycarbonate. Socket outlets shall be flush mounted unless fitted to non-decoratively finished walls or pillars where surface mounting will be accepted. Surface mounted socket outlet shall be metal clad type. Mounting boxes shall be galvanized steel incorporating an earthing terminal and shall accommodate conduit entry for flush mounting or surface mounting. Labels shall be provided on all the front plates to indicate their circuits.

Socket outlets mounted externally or in damp areas shall be weatherproof and shall have a degree of protection of minimum IP 54 to IEC 60529 or BS EN 60529:1992+A2:2013.

Floor-mounting socket outlets shall comprise a recessed galvanized steel floor box, neoprene sealing gasket, metal alloy plug cover cap, and shall be correctly set in the floor slab to ensure that the screwed level adjustments set the unit with the finished floor level.

15A socket outlets shall be of the shuttered type, complying with BS 546, and shall accept two pole and earth round pin plugs and have switches with a rocker type lever. Details of finish and mounting boxes shall be the same as for 13A sockets.

Metal clad switched socket outlet shall be manufactured from rugged heavy gauge steel with lacquer finish. Knock outs for conduits entry shall also be provided on the steel boxes. The cover plate shall also be of steel materials. Heavy-duty three phase socket outlets shall be 32A or 63A 5-pin, complying with BS EN 60309.

Where required, emergency power sockets for Fire Services Department shall be provided in headwall units, tail wall units and other locations shown on the Drawings. The socket outlet shall be 32A, three phase, 5 pin socket outlets, in red colour, to minimum IP 54 in accordance with IEC 60529 or BS EN 60529:1992+A2:2013.

All 32A, three phase, 5 pin weatherproof and heavy duty socket outlets shall be supplied complete with appropriate plugs.

Fused connection units shall be employed for final connection to the fixed equipment or appliances which have a full load current not exceeding 13 A. The front plates shall be made of polycarbonate. They shall comply with the requirements of BS 5733 and BS EN 60670-1:2005+A1:2013 and provide with an outlet for flexible cable. Each fused connection unit shall be complete with a fuse link to BS 1362 rated to suit the appliance to be fed. An earth terminal shall be provided for the connection of the circuit protective conductor to the appliance.

Wherever specified on the Drawings, integral double pole switch and neon light indicator shall be provided as part of the fused connection unit.

2.12 Isolators

Isolators shall be weatherproof high impact polycarbonate switches mounted rigidly on the equipment frame, the adjacent wall or on an approved galvanized mild steel bracket at the right hand side of the motor, viewed from the non-drive end. Isolators shall be of adequate rating for the use to which they will be put under working conditions.

Where motors are assisted start, the switch shall be equipped with auxiliary contacts so connected that when switched off they de-energize the run contactor and force a complete start sequence on re-closure.

Electric motors shall be protected by the following isolators on a three phase supply with AC3 rating to BS EN 60947-3.

a) 0 to 30 kW 63 Amp
b) 30 to 45 kW 100 Amp
c) 45 to 75 kW 200 Amp

Extended terminals shall be used to allow front terminating of cables. Crimped lugs shall be used on cables being terminated at the isolator. For starting drives above 2.2 kW (3HP) isolators shall be four-pole type.
In all cases, the isolators shall be of a kind which permits removal of the switch plate and/or actuating mechanism, and subsequent full access to all terminal screws without removing the switch mechanism itself from the enclosure and disturbing any cabling.

Fireman isolation switch shall comply with Jabatan Bomba's Requirement and IET Wiring Regulation 18th Edition. All Fireman isolation switches location is indicative and shall be approved by the The Contractor or his representative prior installation.

2.13 Connection Boxes

Connection boxes shall be flushed mounted similar to back boxes for switched socket outlets and isolators. The flushed steel boxes shall be zinc electro-plated for good earth continuity and protection against rust and corrosion. The plating shall include a chromate passivation process to provide a better degree of protection.

Brass earth terminals complete with brass fixing screws shall be provided. A blank steel plate with suitable fixing centers shall be provided. Suitable connections for incoming as well as outgoing cables with appropriate ratings shall be provided.

2.14 Terminal Blocks

The rated voltage of terminal blocks shall be 400V between terminals, 230V to earth. Terminal blocks shall comprise brass tubular connectors with screw connections contained within a molded block suitable for working temperature up to 100°C.

Terminal blocks shall be designed to clamp the conductor between metal surfaces with sufficient contact pressure but without causing damage to the conductor. With the largest recommended conductor in position and tightly clamped, there shall be at least two full thread pitches of the screw engaging in the connector.

Disconnect type terminal blocks shall be used for terminals designated to receive signals for control and monitoring purpose and/ or where frequent maintenance is required. Cage-clamp type terminal blocks shall be used where frequent vibration is expected.

IP ratings for terminal block enclosures shall be as follows:

a) Indoor Areas : Minimum IP31
b) Outdoor Areas : Minimum IP54.

3.0 LIGHTINGS SIMULATION REPORT AND CERTIFICATION

Sub-Contractor will be responsible for the submission of all illumination reports for every individual space or rooms. All relevant certifications and product catalogues are to be provided together with the test reports to The Consultant or his representative for approval prior to installation.

Sub-Contractor shall submit to The Consultant or his representative the catalogues, certifications (including SIRIM and IEC/BS compliance) and simulation reports for all space and rooms. Sub-Contractor shall make available to The Contractor or his representative the catalogues, certifications (including SIRIM and IEC/BS compliance) and simulation reports for individuals' lamp and fittings.

All tests, to show compliance with the specifications and manufacturer's standards shall be performed.

4.0 AIRCRAFT WARNING LIGHTS

The Sub-Contractor shall supply and install the Civil Aviation red lights at the highest corners of any structure above the roof top of the tall building, where indicated in the Tender drawings, to the approval of the Local Authorities, CAAM (CIVIL AVIATION AUTHORITY OF MALAYSIA), and the Consulting Engineer.

The lights shall be normally located diagonally across the roof structure, unless otherwise specified.

The wattage of each lamp (weather proof IP 67), corrosion & chemical resistant shall be of the 20 watts per LED projector (removable type with white and red LED circuits). The adjustable flashing rate: 20-60 fpm (flash per minute). Default 25fpm. The lens should be crystal clear PMMA automotive grade lens resist UV & yellowing. It should be compact, light weight, robust, highly resistant to shocks & vibrations. The lights shall be controlled by a 24 hour time switch or photocell and operated within the times specified, normally from dusk to dawn. To include the control panel with flashing RED colour, LED lamp type, ON/OFF Sensor, surge protection for lamp head (internal) & (external) control panel (IP 55) on AC 40kA & DC 40kA..

The lights shall be suitably operated on a 230V, 50 Hz AC. mains supply.

All wiring to the fittings shall be in concealed or surface mounted GI conduit and shall be linked with the copper earthing that are installed at the roof top of the building. To include necessary mounting brackets

The equipment to be offered and proposed by the Sub-Contractor shall be submitted to the Consulting Engineer for approval prior to carrying out the work.

5.0 SAMPLES

One sample shall be provided, unless otherwise specified, of each type of luminaire used for approval by the Architect. Where a light fitting incorporates emergency lighting only that sample incorporated emergency lighting shall be submitted.

Manufacture of luminaires shall not proceed until approval of the prototype, sample or shop drawing as applicable, has been obtained.

Samples of the light fittings shall be handed over to the Main Contractor after approval has been obtained. The Main Contractor shall hold the sample and return it to the sub-contractor immediately prior to practical completion.

END OF SECTION

ESLG - STREET AND COMPOUND LIGHTING

CONTENTS

ESLG - STREET AND COMPOUND LIGHTING

1.0 GENERAL

1.1 Scope of Work

The works shall consist of the supply, install and delivery to site, the lanterns, ballasts, bracket arms, columns, bases, cables, cable laying, ducting, junction box, feeder pillars and all necessary ancillary equipment for the assembly, erection, connection, testing and commissioning of the complete street lighting system in accordance with the details as shown on the drawings and specified here in.

1.2 Code and Standards

This section shall be designed and constructed in accordance with the latest revision of the following standards and the appropriate MS/BS/IEC;

Standards	Document Titles
BS 60228:2005	Conductors of insulated cables
BS 5467	Electric cables. Thermosetting insulated, armoured cables of rated voltages of 600/1 000 V and 1 900/3 300 V for fixed installations. Specification
BS EN 61386-25:2011	Conduit system for cable management – Particular requirements. Conduit fixing devices
BS EN 197-1:2011	Composition, specifications and conformity criteria for common cement
IEC 598	Luminaires
MS 825	Code of Practice for the Design of Road Lighting
MS IEC 60529	Degrees of Protection Provided By Enclosures (IP Code) (First Revision)
IEC 62471	Photo biological Safety of Lamps and Lamp Systems
UL746C	Polymeric Materials - Use in Electrical Equipment Evaluations
BS EN 40-3-1:2013	Lighting columns. Design and verification. Specification for characteristic loads.
BS 5489-2:2016	Code of practice for the design of road lighting. Lighting of tunnels
IEC 60439-1:1999+A1:2004(E)	Low-voltage switchgear and control gear assemblies – Part 1: Type-tested and partially type-tested assemblies
IEC 60439-5:2006	Low-voltage switchgear and control gear assemblies - Part 5: Particular requirements for assemblies for power distribution in public networks
MS IEC 60364	Standard: Electrical Installations of Buildings
BS 7671	Requirements for Electrical Installations
BS EN IEC 60947	Low-voltage switchgear and control gear
IEC 60898	Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations

2.0 EXTERNAL CABLING SYSTEM USING ARMOURED CABLES (PVC/SWA/PVC)

2.1 General

All cables shall be manufactured to the relevant BS standards. The conductors shall be high-conductivity, plain annealed copper conductors complying with BS 60228:2005. The cables to be supplied unless otherwise specified, shall be of the following type, as indicated in the Drawing.

a) For PVC insulated steel wire armoured and PVC sheathed overall (PVC/SWA/PVC) cables manufactured to BS 5467.

b) For cross-linked polyethylene insulated steel wire armoured and PVC sheathed overall (XLPE/SWA/PVC) cables manufactured to BS 5467.

2.2 Cable Termination

Compression type brass glands for cable termination shall be supplied by this Sub-Contractor. The design of the compression glands shall be such that they shall not twist the cable when tightened.

They shall provide facilities for efficient bonding and termination of armoured wires and project at least 20mm into the termination box. This is to prevent condensation collected in the termination box from flowing down between the outer PVC sheath and armoured wires.

The design shall ensure that the gland seal shall enclose at least 20mm of the PVC sheath. It shall be possible to erect and dismantle the cable compression gland without the use of special tools.

2.3 Separate Termination

All cables entering or leaving terminal boxes shall be provided with separate terminations so that any cable out of a number of such cables can be removed or replaced without effecting the others.

2.4 Straight through Joints

No straight through joints shall be used.

2.5 Cable Laying and Installation

a) General
The installation of cables shall include the laying, drawing into HDPE corrugated ducts, erecting and fixing in accordance with this Contract.

The works shall also include the excavation of trenches for the laying of the above PE twin wall HDPE corrugated ducts, including all guarding, - lighting, the removal of accumulated water in trenches such as could be dealt with by normal pumping, the removal and disposal of all materials, the provision and removal skeleton timbering and the slinging, strutting and shoring of other works within the trench, the filling in of all trenches and the interim restoration including re-turfing where necessary.

b) Cable Laying Tools
The Sub-Contractoris responsible for the provision of cable jacks, cable drum axle, rollers and wire stockings. Suitable tripod and lifting block and tackle or hoist or mobile crane shall

be provided by the Sub-Contractor. All barricades, lamps, road danger signs and road boards are to be provided by the Sub-Contractor.

Suitable mechanical and metal shod hand rammers for consolidating of trenches shall be provided by the Sub-Contractor, one hand rammer being provided for every 40 metres of open trench.

c) Cable Laying Materials
All sand required for filling of trenches shall be pit or river sand.

Duct tiles shall be provided by the Sub-Contractor.

Galvanized-Iron pipe are to be provided at road crossings for the laying of cables. Ducts shall be of Grade B and shall comply with BS 6099-1:1981.

PE twin wall HDPE corrugated ducts shall have an internal diameter of approximately double the overall diameter of the cable to be drawn through.

Cable laying materials such as bricks, ducts, etc. may be inspected at the suppliers' depot by The Contractor or his representative before acceptance.

d) Concrete and Mortar
Unless otherwise approved, concrete shall consist by volume, one part of slow-setting Portland cement complying with BS 12, two parts of sand and four parts of gravel or broken stone. Sand shall be clean and free from salt, ligneous, earthly, organic or other impurities. Sea-shore sand, unwashed pit sand or unwashed gravel shall not be used. All gravel or broken stone shall not be more than 50mm square but shall be retained by a mesh 7mm square. All sand shall be screened through mesh of not more than 6mm square. Water shall be clean and free from salt, acid or lime solution.

Concrete or mortar shall be placed in position within thirty minutes of mixing.

e) Trial Holes
Trial holes shall be made as and when required by The Contractor or his representative and if incorporated in the trench will be measured in the run, unless backfilled prior to the installation of the cable.

f) Excavation of Trenches
The exact location of each trench shall be determined on site.

Trenches shall be kept as straight as possible and each trench shall be excavated to an approved formation and dimensions and shall have vertical sides which shall be timbered where necessary so as to avoid subsidence and damage. The bottom of each trench shall be firm and of smooth contour. Any turf removed shall be cut and stacked for re-use in a manner such that it is maintained in good condition. It shall be watered as necessary.

The material excavated from each trench shall be placed so as to prevent nuisance or damage to adjacent hedges, trees, ditches, drains, gateways and other property or things. Excavated material shall be stacked on the far side of the trench from the roadway so as to avoid undue interference with traffic. Where, owing to traffic or other considerations, this is not permissible, the excavated materials shall be removed from site and returned for refilling

the trench on completion of laying. Surplus material shall be disposed of by and at the cost of the Sub-Contractor.

In order to facilitate the re-use of excavated materials for road foundations, and surfacing, the excavated material shall be separated into hard road metal, turf, soil and other materials. The trench excavation and filling shall be so executed that all railways, walls, road sewers, drains pipes, cable, structures, places and things shall be reasonably secure against risk of subsidence or injury and shall be carried out to the satisfaction of the authorities concerned. Where trenches pass a footway to a roadway or at other positions where a change of level is necessary, the bottom of the trench shall rise or fall gradually. The rate of rise or fall shall be approved.

The Sub-Contractor shall deal with the disposal of water so as to prevent any risk of the cables and other materials to be laid in the trenches being detrimentally affected. The Sub-Contractor shall provide all pumps and appliances required and shall carry out the necessary pumping and baling.

Unless otherwise agreed, provision shall be made during excavation and until interim restoration has been completed, for reasonable access of persons and vehicles to property or places adjacent to the route.

When the excavations for trenches have been accurately executed, notice shall be given by the Sub-Contractor to The Contractor or his representative. Laying of PE twin wall HDPE corrugated ducts shall not be started until the Sub-Contractor has obtained The Contractor or his representative's sanction to proceed with the work.

The method of conducting all work shall conform to the requirements of The Contractor or his representative.

g) Cable Trench

All cables shall be laid in PE twin wall HDPE corrugated ducts direct in the ground at a depth of 750mm below ground level.

The normal width of trench for a single PE twin wall HDPE corrugated ducts run shall be 450mm in order that the PE twin wall HDPE corrugated ducts may be properly handled on rollers at the bottom of the trench. This width may have to be increased when it is required to run more than one PE twin wall HDPE corrugated ducts, the increase in width to depend on the number of ducts to be run and their axial spacing. When the trench has been excavated it shall be thoroughly inspected along its entire route and all stones and any other objects likely to damage the ducts shall be removed. The bottom of the trench shall then be covered with river sand for 100mm deep and the duct laid on top. After laying, the ducts shall be covered by a 100mm layer of river sand carefully rammed down. Standard type ducts tiles shall then be placed endwise over the whole length of ducts. The trench shall be backfilled with excavated material, well-watered and rammed down in 150mm layers.

h) Obstructions

When in the course of the Contract works, obstruction are encountered which necessitate diversion of, or alterations to electric, water or sewage installations, telephone or telegraph cables or other underground works, or alterations to buildings or foundations or when conditions necessitate the adoption of special form of trench, the Sub-Contractors shall

immediately notify The Contractor or his representative who will arrange for the Sub-Contractor to proceed with such works as may be necessary.

i) Warning Signs and Lanterns

Where work is being carried out beside any public road, warning signs must be erected. The form, placing and height of warning signs must comply with the Road Traffic Ordinance and danger signs.

Where it is necessary for any trench or pit to be left open overnight red warning lanterns must be placed at each end and at intervals not greater than 10 meters. In built up areas barricades must be erected along the length of the cable trench or pit in addition to warning lanterns.

j) Method of Laying HDPE Corrugated Ducts and Cables

All PE twin wall HDPE corrugated ducts shall be laid and jointed in an approved manner. After ducts have been laid they shall be thoroughly cleaned. A mandrel of diameter slightly less than the duct shall be drawn through. After the mandrel has been drawn through the ducts, a draw wire of gauge 6mm dia. galvanised steel shall be left in each duct to facilitate the drawing in of cables. When required, the Sub-Contractor shall arrange for the ends of all ducts to be capped for water tightness in an approved manner. Ducts shall be plugged to prevent ingress of foreign matter.

Cables shall be drawn into HDPE corrugated ducts laid in troughs or supported in cleats as required by The Contractor or his representative.

Unless otherwise approved auxiliary cables shall be laid under the same covers as the power cables where the latter are laid direct in the ground. Where power cables are laid otherwise than direct in the ground, the auxiliary cables may be laid separately in an approved manner.

No cable may be laid unless The Contractor or his representative is present or has otherwise given permission in writing for work to proceed.

The Sub-Contractor must arrange to test the cables with a 500 volt Megger before laying and when laying of each drum length is complete.

k) Care of Cables

Great care shall be exercised at all times to avoid damage to cables. Drums must not be dropped and must only be rolled smoothly in the direction of the arrows painted on the drums.

At no time should the cable be twisted nor kinked nor should it be bent more than is absolutely necessary to handle the cable. The radii of bending must never be less than 12 times the overall diameter of cables up to 50mm in diameter or 20 times the overall diameter of cables greater than 50mm in diameter.

When running out, the drum must be mounted on firmly supported jacks and the cable pulled off the bottom of the drum. The pulling rope must be attached to the cable by a wire stocking of the correct size with a swivel if required.

After any cable has been laid and until the whole of the cable to be laid in a trench have been covered with their protective covers, no sharp metal tools such as changkols or spades shall be used in the trench. Rollers used during the laying of cables shall have no sharp projecting parts liable to damage the cables.

l) Crossing of Drains, Other Services, etc
Where it is necessary to cross drains, other services or similar obstruction cables shall be drawn into PE twin wall HDPE ducts. The ducts, shall be supported at each end in a concrete block and shall project blocks into the ground at a depth of at least 750mm. The ducts shall project the drains or other services by 600mm but shall not be less than 3.0m in length.

m) Clearance Between Services
The minimum distance between relevant services shall be as follows:-

(i) Parallel Runs
- Between power cables and telephone cables - 500mm
- Between power cables and monitoring cables - 500mm
- Between power cables and water pipes - 500mm
- Between power cables and sewerage pipes - 500mm

(ii) Intersection of services
Where crossing of services is unavoidable power cables shall be maintained at a depth of 1.0m and there should be a minimum vertical clearance of 300mm between cables and other services.

n) Cable and Joint Markers
Concrete cable marker of size 300mm by 225mm shall be provided and installed along the cable routes. Markers shall be inscribed with the words 'L.V. Cable" or "Cable Joint" as appropriate and shall be of size 100mm.

Cable markers will be sunk in the ground at an average interval of 50 metres along the route and joint markers at joint positions. Closer interval should be adopted at places of change of direction to clearly indicate the change of direction. The markers shall protrude above the ground level by 25mm. All cables where conductors are exposed during works shall be capped temporary so as not to allow for the moisture to creep.

o) Cable Records
Cable records drawings showing the exact route of cables and positions of all joints, etc. shall be submitted for The Contractor or his representative's approval.

3.0 MATERIALS AND EQUIPMENT

3.1 General

Items of equipment and material shall have maker's specification complying with those of British Standards. The equipment offered shall be suitable for continuous trouble free operation under adverse conditions.

3.2 Spares

All spares supplied shall be strictly interchangeable with the parts for which they are intended to be for replacements and shall be treated and packed for long storage. Each spare shall be closely marked or labeled for purposes of identification.

3.3 Labels

Labels shall be provided to identify all items of equipment, circuits, cables and where applicable current rating of fuses and setting of relays. Labels on the exterior of equipment shall be clear perspex, reverse engraved, filled flush with black (or red as suitable) filling and the back portion painted the same colour as the equipment. Labels shall be attached by means of machine screws and nuts for machine screws driven into drilled and tapped holes.

4.0 MATERIAL SUPPLY

All equipment and materials offered shall be of an approved type complying with BS standard and Code of Practice or any other internationally recognised standards or codes.

The Sub-Contractor shall be responsible for the co-ordinated functioning of all components and fabrication of finished product. All component parts shall be designed so as to ensure their proper co-ordinated functioning and operation. All equipment shall be of the maker's standard models and shall include all recent improvements in design and materials. All materials used in manufacture and construction shall be of high quality and shall conform to the best current engineering practice. The equipment offered shall be tropicalised and suitable for adverse climatic conditions of heavy rain, high humidity and intense sunlight. The equipment shall be able to withstand ambient air temperatures varying from 40˚C to a maximum of 50˚C.

The design concept for the decorative street lighting column shall accompany with the following:-

a) Design Principle
b) Fabrication Procedure Including Accessories
c) Material
d) Dimension and Tolerance
e) Welding
f) Galvanizing
g) Tests and Test Certificate
h) Computer Printout
i) Design Calculation

The column shall be designed to withstand the following loadings:-

a) Wind loads - at basic wind speed of 35 m/s
b) The loads due to the weight of the column, luminaire and cross arms.

For the purpose of foundation design, ground reaction values shall be summarized and shown on the calculation printout. The required values shall include the overturning moment, shear force, torsional moment and axial load imposed at the base of the column when maximum loads are applied.

5.0 STREET LIGHTING LANTERNS

All lanterns shall be new, totally enclosed, dustproof, insect proof and watertight and shall be tested in accordance with BS 4533-102.51:1986 or IEC 598. Each lantern shall be supplied complete with all the necessary integral control gear fully wired and ready for erection.

The lantern wiring shall be of a size and insulated with materials that will more than effectively withstand the current, voltage and temperatures expected within the lantern during both the starting and operating modes in the ambient temperature and to the operating temperature.

6.0 LIGHT EMITTING DIODE (LED) LUMINAIRE

6.1 General

Luminaires utilising Light Emitting Diode (LED) as light source are also known as Solid State Lighting (SSL).

Solid State Lighting (SSL) i.e LED luminaire system shall be complete with electronic control gear (driver), thermal management unit, surge & overvoltage protection and design for side entry suitable for supply voltage of 230 Volt, +10%, -6%, 50 Hz.

Computer simulation for lighting level calculation shall be supplied (prepared and submitted) to meet the design criteria and lighting class required in accordance with MS 825: Code of Practice for the Design of Road Lighting. The simulation shall be generated using internationally recognised design software. (e.g. Dialux, Calculux, Ulysee etc.)

6.2 Conformity with Standards

All products proposed must have product certification from accredited certification bodies.
LED luminaire shall be tested to comply with the current prevailing standards as below and of latest version:-

No.	Item	Relevant IEC Standards	Name of standard
1.0	**Luminaire**		
1.1	Safety	MS IEC 60598-2-3	Luminaires - Part 2-3: Particular Requirements – Section 3: Luminaires for Road and Street Lighting
1.2	Performance	MS 62722-1	Luminaire Performance – part 2-1 : Particular Requirement for LED Luminaires
1.3	Performance	IES LM-79-08	Approved Method: Electrical and Photometric Measurements on Solid State Lighting Products
1.4	Performance	IES TM 21-11	Projecting Long Term Lumen Maintenance of LED Light Sources
2.0	**Control Gear (LED Driver)**		
2.1	Safety	MS IEC 61347-2-13 IEC 61347-2-13	Lamp Control Gear – Part 2-13 – Particular Requirement for DC or AC supplied Electronic Control Gear for LED Modules.

No.	Item	Relevant IEC Standards	Name of standard
2.2	Performance	MS IEC 62384 IEC 62384 ed 1.1	DC or AC supplied Electronic Control Gear for LED Modules – Performance Requirements
3.0	**Lamp Holder**		
3.1	Safety	MS IEC 60838-2-2 (IEC 60838-2)	Miscellaneous lampholders – Part2-2 – Particular Requirements – Connectors for LED Modules.
4.0	**LED**		
4.1	Term & Definition	MS IEC 62504 IEC 62504 (Ed. 1)	General Lighting: LEDs and LED Modules – Terms and Definition.
4.2	Performance (General)	IEC / PAS 62707 Ed. 1	LED – Binning – Part 1: General Requirements and White Grid
4.3	Performance (Modules)	MS 62717	LED Modules for General Lighting – Safety Requirements
4.4	Performance (Lamps)	IEC/TR 61341	Method of Measurement of Centre Beam Intensity and Beam Angle (s) of Reflector Lamps
4.5	Performance (Light Source)	IES LM-80-08	Approved Method: Measuring Lumen Maintenance of LED Light Sources
4.6	Safety (Modules)	MS IEC 62031 IEC 62031(Edition 1.0) AMD.1.ed 1	LED Modules for General Lighting – Safety Specifications
4.7	Safety (Lamps)	IEC 61231	International Lamps Coding Systems
4.8	Safety (Eye Protection)	IEC 62471 ed 1.0	Photobiological Safety of Lamps and Lamp Systems
4.9	Safety (Eye Protection)	IEC/TR 62471-2	Photobiological Safety of Lamps and Lamp Systems – Part 2: Guidance on Manufacturing Requirements Relating to Non-Laser Optical Radiation Safety
5.0	**Connector**		
5.1	Safety	IEC 61984	Connectors – Safety Requirement and Test
6.0	**EMC**		
6.1	Performance	IEC 61547 Edition 2.0	Equipment for General Lighting Purposes – EMC Immunity Requirements
6.2	Performance	IEC 61000-3-2 Edition 3.2	Electromagnectic Compability (EMC) – Part 3-2: Limits – Limits for Harmonic Current Emmissions (Equipment Input Current ≤16 A per phase)
6.3	Performance	CISPR 15:2005 (BS EN 60079-6:2007)	Limits and Methods of Measurement of Ratio Disturbance Characteristics of Electrical Lighting and Similar Equipment

No.	Item	Relevant IEC Standards	Name of standard
7.0	**Lighting Design**		
7.1	Performance	MS 825	Code of Practice for The Design of Road Lighting

6.3 Construction and Components

The luminaire shall be so designed and constructed that it is capable of providing the service for which it is intended. Sound engineering principles shall be adopted throughout and the luminaire shall be designed to enable ease of maintenance and replacement of light source, optical lens, electronic control gear, thermal management unit, reflector and holder without the use of special tools.

The main supporting structure of the luminaire shall be constructed from die-cast aluminium alloy material such that no undue deterioration in its safety, performance or appearance during normal life when operating in all climatic conditions prevailing in a tropical country such as heavy rains, strong winds, high humidity and hot day-time temperatures. It shall be robustly constructed to withstand vibration in normal use.

The luminaire shall be designed so that condensation shall not fall on any operating part which may fail or deteriorate the performance of luminaire.

All luminaires shall be new, totally enclosed and protected against contact with live or moving parts inside the enclosure. Ingress Protection Index (IP) of LED luminaire shall be minimum IP65. Full details of the IP system can be referred to in MS IEC 60529.

The compartment for electronic control gear and light module shall preferably be separated. Access to the electronic control gear (driver) compartment shall preferably be from the top.

Material used for the construction of the luminaire shall be recyclable.

Hinges, screws and clips if used, shall be robust and made of stainless steel, simple to operate and shall not be liable to accidental detachment during installation or maintenance.

In the open position, it shall be attached in such a way that there is no likelihood of it becoming accidentally detached and thereby damaging any part of the luminaire, the bracket or the column. Attachment of the luminaire to its bracket arm shall be by means of clamps or jam bolts and designed to accommodate spigot size of the luminaires. A minimum of two (2) locking bolts / jam screws shall be provided.

The minimum penetration depth of the bracket arm is 100mm. The mounting arrangement and attachment of the luminaire shall be such as to withstand a windspeed of 42 m/s on the projected surface of the assembly without due deflection.

All parts which carry the weight of the luminaire and internal accessories shall be provided with suitable locking devices to prevent the dislodgement of any part of the luminaire by vibration either in service or during maintenance.

All parts shall operate well within the ratings with due consideration for the local conditions (high humidity of 80% RH, hot (live) ambient temperature of 350C).

Interchangeability of consumable components is preferred for maintenance purposes.

a) Light Source

The light source for LED luminaires shall be of high powered LED type. The LED light module shall not be driven more than the rated LED drive current.

The lumen output of LED luminaires (system efficacy) shall be minimum 85 lm/W. The usable lifetime of LED (lumen maintenance) at 50,000 hours shall not be less than 80% (L80 @ 50,000 hours). The system efficiency shall take into consideration the LED efficacy, driver efficiency, optical efficiency and thermal efficiency and shall not be less than 80%.

The Correlated Colour Temperature (CCT) for LED luminaire shall range between 2500K to 3500K.

Photobiological safety of LED module or LED luminaires shall not be more than Risk Group 1 (as per IEC 62471).

b) Optical System

The optical system shall comprise of optical lens, reflector (if any) and luminaire cover.

(i) Optical Lens
The optical lens shall be made of UV resistant material (eg. poly methyl methacrylate (PMMA), UV stabilized polycarbonate, silicon, etc) and shall be stabilised against deformation, deterioration or discolouration due to the lamp and/or solar radiation (UV).

(ii) Reflector
The reflector if any shall be made of at least 99.85% pure aluminium with a minimum thickness of 1 mm, be electrically brightened, anodised and chemically treated to give high reflectance.

(iii) Luminaire Cover (Secondary Optics)
Luminaire cover shall be provided to protect the optical lens from accumulation of dust and for easy cleaning of the luminaire. It shall be made UV resistant material suitable for outdoor used (in accordance with standard UL746C or equivalent).
For covers that is designed as light diffuser/disperser, it shall be made of clear tampered glass.

(iv) The gasket used shall be silicone, one-piece weather resistant type that will not cause crazing of the luminaire cover. The gasket shall form an integral part of the luminaire cover such that any cover change will necessitate a change of the gasket.

c) Thermal Management Unit

The luminaire shall be provided with suitable thermal management unit to effectively dissipate heat generated from LED.

d) Electronic Control Gear (LED Driver)

Electronic control gear (LED driver) shall comprise of electronic circuit board, converter, built-in power factor correction unit (≥0.9), internal surge protective device (SPD) and THD <20%. The driver shall be able to withstand short circuit current, overload, over voltage and over temperature. The driver shall have self cooling system. LED driver shall be placed close to LED where possible to reduce electromagnetic interference.

The input range of the driver shall function correctly at the supply voltage and shall allow for normal variation and surges (230V, +10%, -6%, 50 Hz).

The working temperature for the driver shall suit the local condition.

Ingress Protection Index (IP) of the driver shall be minimum IP65 as per MS IEC 60529.

e) Surge Protective Device (SPD)

(i) Internal/Built-In SPD
The driver shall be protected against lightning surge with an internal surge protector device (SPD) of not less than 15kA with a let-through voltage of less than 350V test at 2kV, 1.2/50µSec open circuit and 1kA, 8/20µSec short circuit.

(ii) External SPD
To enhance the driver life span and prolong the internal SPD performance, the external SPD may be installed within the column after the modular termination box for safety and ease of maintenance.

If required, the external SPD shall be rated not less than 20kA with a let-through voltage of less than 850V tested at 6kV, 1.2/50µSec open circuit test and 3kA, 8/20µSec short circuit test.

The SPD shall be Full Mode (L-N, L-E, N-E) protection with a working voltage of 275Vac series connection and complete with LED indicator.

f) Capacitors

Capacitors shall be manufactured to BS EN ISO 4017:2014 and housed in extruded aluminum canisters with shrouded screw terminals. They shall not be fused but shall have an external safety discharge resistor. The capacitor shall be capable of raising the power factor of each circuit to at least 0.85 lagging.

g) Ignitors

Ignitors for the discharge lamps shall be of the electronic/superimposed pulse type rated for the appropriate wattage. The unit shall be capable of operating on a voltage ranging from 200 to 250 volts. The unit shall be totally enclosed with an external terminal block for the supply connection and a length of high-tension cable shall be included for the lamp connection. It shall be compatible with the normal control gear. The case of the unit shall carry a label showing the connections and listing the appropriate voltage.

h) Internal Wiring and Earthing Terminal

(i) Internal Wiring
The luminaire shall be completely pre-wired, requiring only the connection of the electrical power supply cables to the terminal and the earth continuity conductor to the earthing terminal.

(ii) Earthing Terminal
A separate terminal for the connection of an earth continuity conductor, clearly and permanently marked shall be provided. The installation shall comply with MS 60364. All exposed metal parts and other parts accessible when the luminaire is opened for maintenance and liable to become live in the event of an insulation fault shall be permanently and reliably connected to this earthing terminal.

6.4 Computer Simulation for Lighting Level Calculation

Computer simulation for lighting level calculation shall include Photometric Data which compromises for the following:

a) Isolux Diagram

b) Utilization Factor Curves

c) Polar Curves of the following C-Planes : 0°/180°; 90°/270°; maximum intensity plane

d) Downward Light Output Ratio

e) Downward and Upward Flux Fractions

(i) The lighting distribution/scheme shall conform to the following: -

- A minimum average road surface luminance of 1.5cd/m2.
- A uniformity of luminance i.e. L min/L av. of 0.4.
- Lane longitudinal uniformities shall be more than or equal to 70%.
- The threshold increment shall be less than 10%.

(ii) Tenderers are required to furnish comprehensive information and technical particulars

The computer plots shall also be attached.

All the above plots and data shall be certified by the respective manufacturer**.**

6.5 Schedule and Technical Information on LED Luminaires

Sub-Contractor is required to furnish comprehensive information and technical particulars to The Contractor or his representative.

The information required in the attachment shall be completed fully and correctly. All technical data entered therein shall be substantiated with relevant pamphlets and test certificates from the manufacturers or the recognized testing authorities.

6.6 Warranty

a) System Warranty

The manufacturer / distributor shall provide a 5 year warranty certificate for the complete luminaire system to guarantee the long life expectancy and maintenance free luminaire. Warranty declaration shall be provided and duly signed by distributor / manufacturer as per The Contractor or his representative's requirement. Failure in the functioning and operation of the LED luminaire within the warranty period will result in the replacement of the whole luminaire or required components by the manufacturer/distributor at no cost to the Client.

b) Performance Warranty

Luminance and illuminance test shall be carried out every six (6) months during defect notice period, to ensure the performance of the installed system conform to designed requirement. These tests will also confirm the lumen maintenance of the luminaire.
The Sub-Contractor together with luminaire supplier shall carry out the above test and the result must meet the design criteria as submitted in the computer simulation.

7.0 HIGH PRESSURE SODIUM VAPOUR LUMINARIES (HPSV)

7.1 General

All street lighting lanterns shall be completed with integral gears and all fittings including lamps, lanterns, ballast, ignitors and capacitors shall preferably be from the same supplier of the street lighting lanterns.

The lanterns shall be designed for side entry and suitable for use with a High Pressure Sodium Vapour (SON) Lamp and suitable for supply voltage of 230 Volt, +10%, -6%, 50 Hz. The lamps shall have an average 'life hours' of at least 30,000 hours.

Computer simulation for lighting level calculation shall be supplied (prepared and submitted) to meet the design criteria and lighting class required in accordance with MS 825: Code of Practice for the Design of Road Lighting. The simulation shall be generated using internationally recognised design software. (e.g. Dialux, Calculux, Ulysee etc.)

7.2 Conformity with Standards

All products proposed must have product certification from accredited certification bodies.
HPSV luminaire shall be tested to comply with the current prevailing standards as below and of latest version:-

No.	Item	Relevant IEC Standards	Name of standard
1.0	**Luminaire**		
1.1	Safety	MS IEC 60598-2-3	Luminaires - Part 2-3: Particular Requirements – Section 3: Luminaires for Road and Street Lighting
2.0	**Control Gear (LED Driver)**		
2.1	Safety	MS IEC 61347-2-13 IEC 61347-2-13	Lamp Control Gear – Part 2-13 – Particular Requirement for DC or AC supplied Electronic Control Gear for HPSV Modules.
2.2	Performance	MS IEC 62384 IEC 62384 ed 1.1	DC or AC supplied Electronic Control Gear for HPSV Modules – Performance Requirements
3.0	**Lamp Holder**		
3.1	Safety	MS IEC 60838-2-2 (IEC 60838-2)	Miscellaneous lampholders – Part2-2 – Particular Requirements – Connectors for HPSV Modules.
4.0	**HPSV**		
4.1	Lamps	IEC 188 1974 & IEC 622 1980	HPSV Lamps
4.4	Performance (Lamps)	IEC/TR 61341	Method of Measurement of Centre Beam Intensity and Beam Angle (s) of Reflector Lamps
4.6	Safety (Modules)	MS IEC 62031 IEC 62031(Edition 1.0) AMD.1.ed 1	HPSV Modules for General Lighting – Safety Specifications
4.7	Safety (Lamps)	IEC 61231	International Lamps Coding Systems
5.0	**Connector**		
5.1	Safety	IEC 61984	Connectors – Safety Requirement and Test
6.0	**EMC**		
6.1	Performance	IEC 61547 Edition 2.0	Equipment for General Lighting Purposes – EMC Immunity Requirements
6.2	Performance	IEC 61000-3-2 Edition 3.2	Electromagnectic Compability (EMC) – Part 3-2: Limits – Limits for Harmonic Current Emmissions (Equipment Input Current ≤16 A per phase)
6.3	Performance	CISPR 15:2005 (BS EN 60079-6:2007)	Limits and Methods of Measurement of Ratio Disturbance Characteristics of Electrical Lighting and Similar Equipment
7.0	**Lighting Design**		
7.1	Performance	MS 825	Code of Practice for The Design of Road Lighting

7.3 Construction and Components

The lantern shall be so designed and constructed that it is capable of providing the service for which it is intended. Sound engineering principles shall be adopted throughout and the lantern shall be

designed to enable ease of maintenance and replacement of lamp, bowl, control gear, reflector and lampholder, without the use of special tools.

The lantern shall be constructed from corrosion resistant materials such that no undue deterioration occurs in its safety and performance of appearance during normal life when operating in all climate conditions prevailing in a tropical country such as heavy rains, high winds, high humidity and hot daytime temperatures. It shall be robustly constructed to withstand vibration in normal use.

The lantern shall be designed so that condensation shall not fall on any operating part, which may fail or deteriorate as a result.Where the lantern is designed for use with the ellipo-sodial (or pear-shaped) lamp, it must also be able to accommodate the tubular lamp.

All lanterns shall be new, totally enclosed, dust proof, insect-proof and watertight and complies with the relevant BS and IEC Standards.

The canopy shall be of non-corrosive stainless or canopy.

a) Lighting Cover

Hinges and catches of the lighting cover shall be robust and simple to operate and shall not be liable to accidental detachment during installation or maintenance.

The lighting cover or other components giving access to the interior of the lantern shall, in the closed position, be firmly attached to the fixed portion of lantern. In the open position, it shall be attached in such a way that there is no likelihood of it becoming accidentally detached from the lantern.

b) Bowl

The bowl shall be made of strong, non-fragile, heat-resistant and light-stabilised material. Polycarbonate bowl is not acceptable.

The bowl shall form part of the lighting cover.

c) Optical System

The design of the optical system shall be controlled by separate individual reflector or reflectors. The reflector or reflectors shall be made of high purity aluminium polished and chemically treated.

The optical compartment shall be sealed and dust-tight in normal operation, such that the reflector unit and lamp always remain dust-free. Correct tightness shall be ensured on the covers provided for ease of lamp changing, maintenance etc. when close. The gasket used shall be tropicalised and positively retained in its seating position and shall not work loose during and after maintenance. Materials used in the gasket shall effectively prevent the ingress of moisture and shall not deteriorate unduly due to heat, light or compression.

Provision shall be made for the optical compartment to breathe through filters and to keep out dust, air contaminants and the ingress of insects.

The lanterns shall be adjustable for cut-off light distribution for expressways and at least semi-cut-off light distribution for other major roads as per CIE (International Commission of Illumination) definitions.

Adjustment shall be provided in the lantern to shift the main light distribution towards the axis of the road to suit different road widths.

Such adjustment shall be simple and positive and shall be firmly retained in clearly identified positions. Photometric data shall be supplied with each of the possible adjustments.

d) Lampholder, Supports and Brackets

The lampholder shall be complete with brake system to avoid loosening of the lamp and with protective porcelain skirt to avoid an operator coming into contact with live metallic parts.

The lampholder, its supports and brackets shall withstand normal usage throughout the life of the lantern. They shall accept and retain lamps which are within the dimensional tolerances stated in the appropriate British or equivalent standards and shall locate the light source in the correct relation to the optical control device of the lantern.

Insertion and withdrawal of the lamp without undue stress shall be possible. A lamp fully inserted shall be rigidly held with its axis substantially coincident with that of the lampholder under the normal conditions of wind vibration and mechanical shock.

Where provision is made for alternative sizes of lamps, the means of adjustment shall be simple and positive and shall be firmly retained in clearly identified positions.

e) Electric Control Gear

The lantern shall be furnished complete with integral electrical control gear comprising inductive ballast, capacitor and ignitor.

The electrical control gear shall be mounted on a suitable module unit and shall be easily removable and replaceable as a unit without the use of any special tools. Electrical connection and disconnection of the electrical control gear unit from the lantern shall be easily done and terminals easily accessible.

The ballast supplied shall be solidly filled with polyester compound and totally enclosed in sheet steel or die-cast aluminium container or vacuum impregnated with a suitable varnish. The ballast shall satisfy the requirements of BS 4782, IEC 922 and IEC 923 together with all the amendments. A minimum of two tappings shall be provided: one rated at 220V and the other at 240V. The ballast losses during lamp operation shall be within 10% of nominal lamp wattage. The ballast shall be able to operate in an ambient temperature of 50°C for 100W/150W/250W/400W SON lantern (integral mounted). The ballast supplied shall match the lamp for all operating conditions. The lamp current crest factor of the ballast shall not exceed 1.8 for ±6% voltage variations.

The ignitor shall be of the Pulse Transformer type incorporating electronic circuitry and suitable for the type of ballasts and lamp to be installed. The output pulse shall be substantially independent of both supply voltage and ballast parameter. A cut-out circuit

shall be incorporated so that pulsing will cease after approximately two minutes, in the event of no ignition.

The capacitor shall be manufactured to B.S. 4017 and rated at 85°C. The rating of capacitor used shall be such that the power factor of the complete lantern shall always be corrected to be not less than 0.85 lagging.

f) Terminal Block

A readily accessible barriered terminal block with the 'live' and 'neutral' connections clearly and indelibly marked for the connection of the incoming supply cables shall be provided as close as possible to the point of entry of the supply cables.

A means of clamping the electrical supply cables shall be provided in the lantern to relieve the termination of strain. The cable clamp arrangement shall not damage the insulation of the cables.

g) Earthing Terminal

A separate terminal for the connection of an earth continuity conductor, clearly and indelibly marked shall be provided.

All exposed metal parts and other parts accessible when the lantern is opened for maintenance and liable to become live in the event of an insulation fault shall be permanently and reliably connected to this earthing terminal.

h) Internal Wiring

The lantern shall be completely pre-wired, requiring only the connection of the electrical power supply cables to the terminal block and the earth continuity conductor to the earthing terminal.

The wirings used shall be heat resistance type with the temperature rated marked on the insulation.

The wiring inside the column shall be from PVC/PVC single core 2.5mm² copper. The colour of the PVC insulation shall be standardised such that the earth conductor is coloured green or green and yellow, neutral conductor is coloured black and the line conductor is coloured any colour other than green, green and yellow or black.

7.4 Lamp

The lamp to be accommodated in the lantern shall be high-pressure sodium vapour, ellipo-sodial (pear shaped) or tubular, clear or coated to give a golden colour output.

The lamp cap shall be the type as shown in Table 4: -

Table 4:

	100W	**150W**	**250W**	**400W**
Lamp Cap Code	E40	E40	E40	E40

7.5 Computer Simulation for Lighting Level Calculation

Computer simulation for lighting level calculation shall include Photometric Data which compromises for the following:

a) Isolux Diagram
b) Utilization Factor Curves
c) Polar Curves of the following C-Planes : 0°/180°; 90°/270°; maximum intensity plane
d) Downward Light Output Ratio
e) Downward and Upward Flux Fractions

The lighting distribution/scheme shall conform to the following: -

a) A minimum average road surface luminance of 1.5cd/m2 or 2.0 cd/m2
b) A uniformity of luminance i.e. L min/L av. of 0.4.
c) Lane longitudinal uniformities shall be more than or equal to 70%.
d) The threshold increment shall be less than 10%.

Tenderers are required to furnish comprehensive information and technical particulars. The computer plots shall also be attached.

All the above plots and data shall be certified by the respective manufacturer**.**

7.6 Schedule and Technical Information on HPSV Luminaires

Sub-Contractor are required to furnish comprehensive information and technical particulars to The Contractor or his representative.

The information required in the attachment shall be completed fully and correctly. All technical data entered therein shall be substantiated with relevant pamphlets and test certificates from the manufacturers or the recognized testing authorities.

7.7 Warranty

a) System Warranty

The manufacturer / distributor shall provide a 5 year warranty certificate for the complete luminaire system to guarantee the long life expectancy and maintenance free luminaire. Warranty declaration shall be provided and duly signed by distributor / manufacturer as per The Contractor or his representative's requirement. Failure in the functioning and operation of the HPSV luminaire within the warranty period will result in the replacement of the whole luminaire or required components by the manufacturer/distributor at no cost to the Client.

b) Performance Warranty

Luminance and illuminance test shall be carried out every six (6) months during defect notice period, to ensure the performance of the installed system conform to designed requirement. These tests will also confirm the lumen maintenance of the luminaire.

The Sub-Contractor together with luminaire supplier shall carry out the above test and the result must meet the design criteria as submitted in the computer simulation.

8.0 COLUMNS

All columns shall be manufactured to comply with the appropriate British Standards, BS EN 40-3-1:2013. Each column shall have a base compartment and a weatherproof service door, measuring 600mm x 130mm, with a tamperproof Allen Key lock. The door shall be of the same thickness as the column and be flush with the column, providing a water-tight fitting against a non-perusable resilient gasket. Door keys shall be supplied at the completion of the Contract.

The columns shall be supported by flange plates on concrete footings. Flange plates shall be of at least 18mm thickness. Concrete footings shall be cast with appropriately sized holding down bolts as recommended by the column manufacturer and have lead-in/lead-out ducts. The Sub-Contractor shall be responsible for the size and design of the concrete footings depending on soil conditions.

A 16mm thick Tufnol baseboard, measuring 600mm x 130mm, shall be included in the base compartment. The baseboard shall be securely fixed in position inside the column by countersunk screw of hidden type of treaded bushes. No part of this fixing shall protrude through the column. The base board shall be well insulated when fixed to the column.

All metal parts of each column shall be earthed and the column shall be electrically continuous. A corrosion resistant electrical earthing terminal in the form of a stud of not less than 6mm in diameter and 20mm long shall be attached close to the door opening within each column. Two suitably sized washers and two nuts shall be fitted.

9.0 COMPLIANCE WITH MANUFACTURER'S SPECIFICATIONS

The Sub-Contractor shall ensure that the equipment and parts used shall be entirely suitable for the work to be performed and that they shall be manufactured to proper clearance and fit. The Sub-Contractor shall further ensure that the loading of equipment shall under all normal circumstances not exceed the maximum laid down or agreed in writing by the manufacturer.

The Sub-Contractor shall be responsible for the inspection of all equipment and parts before their incorporation in the works to ensure that they comply with the requirements of the specification and that they are not defective in any way as regards materials or workmanship.

10.0 DEFINITIONS

Unless specifically defined herein, definitions shall be as given in British Standard 5489 Part 2: 2016 `Lighting for Traffic Routes' and CIE 12 recommendation.

11.0 OUTDOOR WEATHERPROOF FEEDER PILLARS

11.1 General

The Feeder Pillars shall be supplied completely assembled with control gear and all internal electrical and mechanical interconnections and structural parts for voltages up to and including 1000 volts A.C. It shall comply with and be tested to the requirements of IEC 60439-1:1999+A1:2004(E), IEC 60439-5:2006 and Authorities.

The feeder pillar for outdoor use shall be Form 1 and IP54 degree of protection to IEC 60529, EN 60529 and Malaysian Standards or other internationally recognized equivalent standard approved by the authority.

11.2 Fabrication

The Sub-Contractor shall submit design drawings showing the plan, elevations, sections, layout and construction details of the feeder-pillar for the approval of The Contractor or his representative prior to fabrication.

The plinth, foundation work, ducting, etc. shall be included in the design drawing.

The feeder-pillar housing shall comprise of a drip canopy with sufficient overhang, rigid welded stainless steel framework as specified in the Drawings. Anti-corrosive treatment shall be applied to the pillar and it shall be painted. A non-perishable resilient gasket shall be provided all around the edge of the feeder door.

On the front and rear sides of the feeder-pillar, the following sign and lettering of 90mm height shall be stenciled in red paint.

BAHAYA

VOLTAN ELEKTRIK

400 V

Side panels and front and back doors shall be fabricated from 12 SWG sheet steel. The feeder pillar shall rest on an angle iron base where suitable holes have been prepared to accommodate foundation bolts and to secure the feeder-pillar onto the concrete foundation.

The door of the feeder pillar shall be rigidly reinforced bonded and hinged internally to the main frame to prevent 21unauthorized access. The feeder pillar shall be of lockable type as approved by The Contractor or his representative's -. The feeder-pillar shall be self-ventilated and weatherproof, and such ventilation openings shall be protected by wire mesh to prevent the entry of vermins, rodents and birds.

A suitable size wire mesh glass window shall be provided to facilitate reading of the kWH meter.

A pocket of suitable size for housing A4 size documents shall be fitted onto the inside of feeder-pillar.

The hinged door must be earthed using copper braid.

If a stainless steel feeder pillar is specified, all material including framework, panels, bolts and nuts used in the manufacture shall be totally stainless steel. The side panels and front and back doors shall be fabricated from 14 SWG stainless steel. No additional anti-corrosion and paint treatment are required unless otherwise stated.

The feeder pillar shall be provided with switch socket outlet, fluorescent fitting and 60-watt heater.

11.3 Factory Inspection

The Sub-Contractor shall make arrangements for a joint inspection and to witness the electrical tests at the factory prior to transportation to the site of the feeder pillars. All costs incurred shall be deemed to be included in the contract. Test certificates shall be issued upon completion of all tests.

11.4 Foundation

The site for the foundation of the feeder-pillar shall be excavated and filled where required, compacted and levelled before the reinforced concrete base is constructed to a minimum of 300mm (or otherwise specified) above the finished ground level and 600mm below the finished ground level. Cable slots shall also be provided.

11.5 Earthing

The earthing system for the feeder-pillar shall comply with the requirements of MS IEC 60364, BS 7671, JKR, ST and in accordance with the Drawings.

Each feeder-pillar shall be effectively earthed by using 16mm diameter copper jacketed steel core rods, 25mm x 3mm copper tape and heavy duty inspection chamber with removable cover.

The Sub-Contractor shall supply and install minimum of two number of earth points and interconnection to obtain a resistance of one (1) ohm or as required by the relevant regulation.

11.6 By-pass Switch and Selector Switch

A single and three-phase by-pass switch as applicable shall be connected in parallel with the contactor for use in the event of the failure of the contactor. This by-pass switch shall be manufactured to B.S.5419 and shall be capable of breaking the load connected without undue wear or damage. A four (4) position selector switch shall be provided to select the mode of operation and shall be appropriately labelled.

11.7 Moulded Case Circuit Breakers (MCCB)

All moulded case circuit breakers shall comply with the requirements of BS EN 60947-2:2006+A2:2013 and shall be of the current limited type. Unless otherwise stated, the AC rated short circuit capacity shall be:

a) 10kA for standard rated currents up to and including 30 Amp.

b) 22kA for standard rated currents up to and including 400 Amp.

c) 45kA for standard rated currents greater than 400 Amp.

The MCCB shall incorporate a time delay device to ensure that it will tolerate harmless transient overload unless this is well in excess of 25% of its rated value for a sustained period.

The MCCB shall be able to isolate the fault instantaneously for short circuit current of the order of six (6) to ten (10) times the normal load current.

MCCB shall employ silver tungsten contacts of the high pressure, butt type, ensuring cool operation at full load and shall be equipped with de-ionizing arc chutes for the rapid extinction of arching occurring during overload operation. The breaker shall operate by a toggle-type handle lockable at “Off” position and having a quick make, quick break mechanism and shall be mechanically trip free from handle to ensure that the contacts cannot be held closed against short circuit and abnormal current. Visual indication of the “OFF”, “TRIPPED” and “ON” positions, phase identification colours and appropriate labels shall be provided and shall be able to incorporate auxiliary switch under voltage release and shunt-trip unit, if required units shall be complete with bolted-type neutral link,

links for both supply neutral connection and earthing, screening shutters actuated automatically with the circuit breaker isolated and withdrawn and capable of padlocking in such positions, SN auxillary switches independently adjustable for N/O or N/C automatic release coils and manual tripping device.

11.8 Miniature Circuit Breakers

Unless otherwise indicated in the Drawings and/or Bill of Quantities, miniature circuit breakers (MCBs) shall have breaking capacity not less than 6 kA (rms) and of B-type with Class 3 energy limiting characteristics. They shall comply with IEC 60898, fully tropicalised and suitable for use on a 230/400V, 50 Hz A.C system and in an ambient temperature of 40°C.

They shall be quick-make, quick-break and trip free type complete with de-ion arc interrupters. The tripping elements shall be of thermal magnetic type with inverse time delay overcurrent and instantaneous short circuit characteristics. The response to overload shall be independent of variations on ambient temperature.

They shall be manually operated by means of toggle type handle having visual indication of whether the breaker is opened, closed or tripped. Multiple breakers shall be provided with a common trip mechanism for simultaneous operation of all the poles.

11.9 Termination

All cables terminated into the various components including incoming and outgoing cables must be terminated through compression glands and heat shrinkable sleeves.

11.10 Time Switch

Time Switches of the synchronous motor wound, handset dial, single pole plug-in type shall be installed as shown on the Drawings. The time switch shall be of the circular dial capable of one `ON' and one `OFF' operation per day and with a 24 hour spring reserve. Time switch shall operate load contactors of adequate continuous rating to cater for the loads.

A three position selector switch providing the following operation viz. Auto `ON/OFF', Manual `ON' and Manual `OFF' shall be provided to control the load contactors.

11.11 Photocell

All outdoor lighting shall be photocell switch controlled through a suitably rated latched contactor with time delay incorporated between each circuit to even out the switching peaks.

The photocell sensors are to be located at every feeder pillar and it must not be in any shaded area. A manual by-pass switch shall be provided for every photocell switch.

The photocell switch shall be capable of at least one “ON” and “OFF” operation per day. The photocell switch shall operate load contactors of adequate continuous rating to cater for the loads.

11.12 Maintenance Period

All repairs and replacement including replacement of bulbs required during the Maintenance Period shall be carried out with dispatch and an adequate supply of spares shall be available for this purpose. The replacement shall be made before the next luminance.

12.0 SHOP DRAWINGS

Two sets of prints of shop drawings for construction and/or installation shall be submitted to The Contractor or his representative's Representative for approval. The Sub-Contractor shall prepare and submit shop drawings for the whole work or parts of the work at least two weeks before the work begins. If the shop drawings submitted are not acceptable by The Contractor or his representative. Sub-Contractor shall amend and re-submit the shop drawings within two weeks from the date of return of the shop drawings. No work including fabrication of the feeder pillars shall be carried out without the shop drawings being approved by The Contractor or his representative.

The shop drawings shall include and show the following:

a) The dimensioned general arrangements, layouts and positions of columns and luminaries, feeder pillars, and all others necessary for the complete road lighting installation as specified in the Drawings and/or Bill of Quantities.
b) Circuits and switching arrangements including schematic line diagrams of the installation;
c) The dimensioned general arrangements and layouts of the equipment and the schematic line diagram of the feeder pillars;
d) Cable routes for all cables laid underground, in ducts and trenches;
e) The dimensioned general arrangements and layout of earthing system including routes for earthing conductors and positions of earth electrodes.
f) The cost of all these shop drawings, whether or not provided in the Bill of Quantities, is deemed to be included in the Contract.
g)

13.0 TESTING AND TEST CERTIFICATES

On completion of the installation work on site and before the Certificate of Practical Completion is issued, the Sub-Contractor shall at his own expense, arrange for all necessary tests to be carried out on the installation by competent person as part of the tests required of him for the whole installation under this contract. The tests to be carried out shall be as prescribed in the Electricity Regulations 1994, B.S. 7671, IEC 60364 and other tests deemed necessary by The Contractor or his representative.

In the event the installation fails any of these tests, the Sub-Contractor shall, at his own expense, take such measures as are necessary to remedy the defects and the installation shall not be considered as completed unit it complies with the requirements of all such tests.

The tests to be carried out by the Sub-Contractor shall consist of the following tests (where applicable): -

a) Continuity of final circuit conductors
b) Continuity of protective conductors including main and supplementary equipotential bonding.
c) Insulation resistance
d) Insulation of site-built assemblies
e) Protection by electrical separation
f) Protection by barriers or enclosures provided during erection
g) Insulation of non-conducting floors and walls
h) Polarity
i) Earth electrode resistance
j) Earth fault loop impedance

k) Functional testing of all types of switches and switchgear
l) Alignment and uprightness of the columns and the tilting angle of the bracket arms
m) Luminance and illuminance readings in accordance with the computer plots

Two sets of Supervision and Completion Certificate (Form G-ST) and Test Certificate (Form H-ST) including copies of all the test results and drawings as prescribed in the Electricity Regulations 1994 shall be submitted to The Contractor or his representative within two weeks after the completion of the testing. The aforesaid Certificates shall be properly bound in hard cover and titled.

14.0 SERVICE AND MAINTENANCE

During the Defects Notice Period, the Sub-Contractor shall be responsible for the service and maintenance for the complete installation. All works shall be carried out by competent person. All labour, transport, equipment, materials, tools and parts necessary to service the installation and/or rectify the defect due to manufacturing/installation faults shall be supplied/executed at the Sub-Contractor's cost.

The Electrical Sub-Contractor shall provide a three-monthly report.

The service and maintenance to be performed and defects to be rectified and made good shall include but not limited to the following:-

a) Replacing or making good all luminaires, lamps, electronic control gear and optical system
b) Replacing socket outlets, isolators, MCB, MCCB, fuses, time switches, contactors, relays, meters, etc.
c) Replacing all consumable items that do not meet the manufacturer's guaranteed or declared lifespan
d) Straightening columns and replacing missing doors, covers and locking devices.
e) Replacing and making good all loose/damaged cable terminations, damaged cables, mechanical support linkages, earth electrode chambers and covers, etc.
f) Making good damage to roads, buildings, drains, cables, pipes, concrete areas, paved areas, turfed areas, etc, which was his responsibility to make good but which had not been properly rectified.
g) All other works deemed necessary by The Contractor or his representative.

All works shall be carried out as soon as the Electrical Sub-Contractor is informed by The Contractor or his representative or the owner and shall be completed within a reasonable time except under emergency situation as stipulated in the Supplementary Conditions for Electrical Work. If the Sub-Contractor fails to comply with the above requirements, The Contractor or his representative reserves the right to engage a third party to carry out the work, in which case, the Sub-Contractor shall be responsible for all the expenses incurred.

15.0 AS-BUILT DRAWINGS, MANUALS AND TOOLS

Within three calendar months after the practical completion of the project, one set of true to scale negative (110/115 gm./sq.m. ISO A0 or A1 size) and four sets of prints for each of the following drawings shall be submitted: -

a) Site plan
b) Schematic Wiring Diagrams and Control Circuit Drawings
c) Road Lighting Layout Plans

d) Layout plan of cable routes and earthing points, with reference to easily recognisable landmarks, buildings and structure.

These drawings shall be properly stenciled and shall have at the lower right corner the Sub-Contractor's name and address, date of commissioning, scale drawing number (the drawing number shall be obtained from The Contractor or his representative) and title.

If the drawings submitted are not acceptable to The Contractor or his representative, the Sub-Contractor shall amend and resubmit the drawings within two weeks from the date of notification by The Contractor or his representative.

If required and specified elsewhere, in addition to the aforesaid negatives and prints, the as-installed drawings shall be stored in electronic media or any other media as specified. The electronic media shall be floppy disks and/or CD as specified which can be readily retrieved by computer. The software programme shall be Auto CAD of a release specified or of the latest release. Two sets or copies of the as-built drawings in the format required, appropriately titled and stored in container or casing, shall be submitted.

In addition, four sets of the following manuals/brochures and documents, suitably bound, shall be submitted to The Contractor or his representative.

a) Installation manual
b) Operation manual
c) Service and Maintenance Manual
d) Part List
e) Product data and catalogues
f) Product Test Certificate

Special tools required for the operation, service and maintenance of the feeder pillars and switchgear, columns and other equipment shall also be provided.

The cost of all these prints, manuals and tools shall be deemed to be included in the Contract Price.

END OF SECTION

ETIW - TELEPHONE INFRASTRUCTURE, WIRING AND OUTLETS

CONTENTS

ETIW - TELEPHONE INFRASTRUCTURE, WIRING AND OUTLETS

1.0 GENERAL

The Specification covers the supply of all materials, labour, cartage, tools, equipment and appliances necessary for the construction, installation, testing, commissioning and completion of the work as hereunder more fully described with all consequential and incidental work requisite though not specifically mentioned herein to the true intent and meaning of the Specifications and the accompanying drawings under the direction of and to the satisfaction of the Contractor or his representative.

2.0 RULES AND REGULATIONS

The work shall be executed in accordance with the requirements of Telekom Malaysia Berhad's (TM) Manual on Planning Requirement for Cabling for Telephone Services (Issued Nov 1986), WE 0304 Specification for Construction of Manhole Joint Boxes and Laying of Ducts (1983) and the requirements of the TM and Suruhanjaya Komunikasi dan Multimedia Malaysia (SKMM).

3.0 TECHNICAL AND INSTALLATION REQUIREMENTS

3.1 Telecommunication Incoming Cables

a) The point of cable entry and the method of entry should be decided in conjunction with the architect to ensure that foundations and walls are not damaged. The approximate entry point is shown on drawings.

b) Where an entry hole has to be made in a wall below ground level care shall be taken to seal the hole to prevent water from getting into the building. The sealing shall be to requirement of the TM.

c) The Sub-Contractor shall provide underground pipes and cables pits and cable rack / tray / trunking as required for the incoming cable.

d) Pipes for incoming cable shall:

   (i) Be black coloured.

   (ii) Be rigid PVC ultra-violet stabilised.

   (iii) Be buried 450mm below finished ground level.

   (iv) Be provided with cable markers.

e) Cable pits shall:

   (i) Be of standard type as utilized by TM.

   (ii) Have the TM logo on the cover.

(iii) Be installed so that the lid is flush with finished ground level.

f) The cable shall be terminated on a subscriber distribution frame.

3.2 Ductworks & Manholes

a) Excavation

(i) All roads and footways for cable ductworks and manholes shall be kept open to minimise interference to traffic and pedestrians.

(ii) In no case shall the width of trench excavated be greater than is necessary for satisfactory execution of the work. The line of the excavated trench shall be as straight as possible and any bends or curves shall be of the maximum radius possible.

(iii) In unstable ground and where ducts have to be encased in concrete, timbering may be necessary to support the trench and can also act as formwork for the concrete.

(iv) The depth of the trenches shall be in accordance with the Telekom's requirements for underground ductwork installation. The base of every trench shall be levelled.

b) UPVC Ducts

(i) The ducting of 100mm diameter UPVC ducts shall be used for normal area and G.I. pipe shall be used for under road area unless otherwise stated. The UPVC ducts shall be concrete encased where required. Concrete used for encasing the ducts shall relatively be dry having consistency of wet sand. In no circumstances shall the water content be increased appreciably as this will result in weak concrete.

(ii) The ducts shall be manufactured from UPVC and of the approved type for use by TM. These ducts shall be 6m lengths and should be stored away from the direct rays of the sun. A solvent cement shall be used for all joints.

(iii) Ducts shall be cut when necessary, at right angles to the bore only, preferably with a saw in a simple cutting guide, the inside edges being afterwards so trimmed that there can be no possibility of damages to cables from the edges.

(iv) The laying and jointing of ducts shall be carried out in accordance to the requirements and supervision of TM and the Contractor or his representative.

(v) The trench shall be scooped out at all points where the sockets rest, so that the body of the duct lies upon solid ground.

(vi) Where one line of the ducts is laid over another in the same trench, sand shall be filled in over the lower line of ducts and carefully rammed to form a

bedding 50mm in thickness or the top ducts. Sand shall also be rammed between the ducts laid side by side in the same trench. The ducts shall break joint by approximately half the duct length in alternative lines.

(vii) If it be necessary to deflect from a straight line or to vary the depth, sets may be given to the joints but deflections shall not be greater than 20mm per meter length of the single ducts. At the discretion of the Contractor or his representative, short ducts not less than one meter in length may be built into the track in order to secure the required deviation, but the deflection must not be greater than that admitted of the tests hereinafter specified being carried edge.

(viii) The spigot and coupling linings of the ducts shall be wiped clean and the V-shaped rubber ring fitted pointing outwards. The lubricant shall be applied to the spigot back to the positioning groove. The lubricated end of the conduit shall be positioned to the coupling and pressure applied by hand to the other end. The coupling should be checked to ensure that it lines up with witness groove on the end of the conduit. Under no circumstances shall dirt or grit be allowed to enter the joints.

(ix) To ensure the alignment of the ducts, a working Mandrel 457mm in length and 83mm in diameter shall be drawn through the ducts are laid.

(x) When the building of a jointing chamber is deferred until after the completion of a section of duct included in the work, the last joint of each duct shall be tested on completion of the jointing chamber by means of the working Mandrel mentioned above.

(xi) After completion of the duct laying, cleaning and testing shall be carried out in the presence of the TM officer and The Contractor or his representative by using a test Mandrel of 457mm length and 83mm in diameter, the cylindrical brush being 108mm in diameter.

c) Manholes

(i) The types of manholes or jointing chambers as specified in the drawings or Specifications shall be accordance with TM requirements. All jointing chambers shall be built of brick or reinforced concrete. Duct seal shall be provided to all ducts leading into any building or enclosure. Duct seals to the TM requirement shall be provided at both ends of the ducts.

(ii) Conduits shall enter manholes at such depth to ensure a clearance of at least 460 mm between the top of the barrel of the uppermost conduits and the underside of the roof of the manhole. Except where a duct seal is provided, when a clearance of 200 mm is required, clearance of 150 mm depending on type of manhole, shall be given between the outside of the barrel of the conduits and the adjacent wall, and a minimum clearance of 460 mm between the underside of the barrel of the lowest conduit and the floor.

3.3 Horizontal Runways/Under Floor Trunking

a) Horizontal cableways or runways are required from the Secondary distribution boxes to all places where telephones may be required. Such cableways should consist of 3 compartment metal flush floor trunking or conduit running in ceiling space as indicated in the drawing to accommodate the cable-pairs required. The conduit/ trunking shall be neatly run in the floor slab/ ceiling.

b) All sections of joints and ducts shall be mechanically continuous and watertight after fixing into position. Where bends are necessary, they shall be maximum radius possible. Elbow bends shall be avoided. Not more than one bend is permitted per junction boxes.

c) Multi-strand nylon draw wire of minimum 4mm diameter shall be provided in pipes and ducts. During concrete operation, pipes and ducts shall be plugged so that they do not become blocked. The trunking shall be incorporated together with junction boxes as deemed necessary. All under floor trunking services shall be designed taking into account a grid system as per Telekom's requirement. Details or samples of the ducting system, junction boxes and pick-up points shall be submitted for the Contractor or his representatives' approval prior to fabrication.

3.4 Type of Cables

a) The cables shall be suitable for operation on a 50 volt D.C. service for use in the telephone installation system. The cables shall comprise the necessary number of wires, each PVC insulated, laid up in pairs and served with an extruded PVC sheath.

b) Telephone cables shall be smooth drawn, pliable, uniform in quality and free from all defects. Telephone lines shall be CAT 3 UTP or two core single mode fiber optic cable and data lines shall be CAT 6 UTP.

c) PVC insulated conductor colours shall be in accordance with colour standards as specified by the TM.

d) For UTP cables, two insulated conductor colours shall be uniformly twisted together with right hand lay to form a pair. The length of lay shall not exceed 100 mm and the lays for adjacent pairs are to differ from one another in length. The cable cores shall be laid up to form a compact and symmetrical cable and if fillers are needed for this purpose they shall be PVC.

e) The direction of lay is to alternate for successive layers, the first layer being preferably right hand.

f) The cable sheath shall be of extruded PVC having a radial thickness of not less than 1.25 mm and containing a suitable quantity of approved termite repellant e.g. lead naphthenate which shall be evenly dispersed.

g) All UTP telephone cables installed externally either above or below ground, shall be jelly-filled type.

3.5 Junction Boxes

a) Junction boxes of dimensions specified in the drawings shall be manufactured from mild steel or concrete to the relevant B.S standard. The boxes shall be installed in the floor slab with concrete finish cover plates installed flush with the finished floor level. The cover of the junction boxes shall be fitted with gasket and shall be water tight. Provision shall be made for the adjustment in the cover installation shall make if flush with the floor finished.

3.2 Distribution Box and Fiber Termination Box

a) Distribution point boxes (including sub-distribution boxes) shall be constructed from galvanized mild steel sheets/heavy duty plastic and suitable for wall mounting in accordance with TM.

b) Distribution boxes shall have the same number of ways as that shown on the drawings and shall be complete with the necessary number of jumper rings. Each way shall be either of the sliding link terminal type or of the unit terminal type to allow conductors to be easily isolated without disconnecting or unsoldering wires and shall be complete with a chart board for recording the circuit connections. Each terminal block shall be engraved with the name of the building and to be complete with screws on both faces.

c) Fibre termination box (FTB) shall be constructed from high quality cold-rolled steel and suitable for wall mounting in accordance with TM. It shall have good dustproof property. In addition, it shall also be compatible for various types of splitter and has enough room for retaining patch cord and pigtail. For indoor application, it shall be top and bottom cable access.

3.6 Jointing of Conductor

a) Joints in individual conductors during the course of manufacture are to be avoided if possible and any such joints, if carried out, shall satisfy the following conditions:-

   (i) The tensile strength of a 250 mm length of conductor containing a joint shall be not less than 95% of similar unjoined sample of the conductor

   (ii) The electrical resistance of a 150 mm length of conductor shall not be increased by 5% due to the inclusion of a joint.

3.7 Installation of cables

a) All single runs of cables shall utilize clamps fixed to the structure of the building and all multiple runs of cable utilize cable trays or trunkings. The design of all clamps shall be such that no pressure is applied to the cable and that the cable is in no way deformed.

3.8 Telephone Wiring Point

a) All telephone points wherever shown in the drawings shall be provided with cables. The number of cable cores required shall be as shown in the drawings.

b) At every telephone point shall be terminated to an approved telephone plug-in

unit/outlet/Fiber Wall socket.

3.9 Main Distribution Frame/Panel

a) The Main Distribution Frame/Panel (MDF) shall be of standing/wall mounted type and must be the type approved by TM and shall be equipped as follows:-

Incoming Line Terminations - As shown on drawing

b) The terminal blocks shall preferably be of the vertical mounting type so as to minimize the possibility of loose ends, solder screws, etc. being trapped in the terminal blocks.

c) The mounting shall be such that each critical of the MDF shall contain terminal blocks for only exchange line terminations or only internal line terminations.

d) There shall be adequate facilities for the labeling of the verticals and terminal blocks.

e) The terminations may either be of the solder type of the wire type or a combination of wire wrap and solder.

f) All terminations for exchange lines shall be equipped with gas- discharge protectors. The gas-discharge protectors may either be the twin-electrode or triple-electrode type.

g) All ferrous metal works shall be pre- cleaned by an approved process and then coated with an approved anti-rust undercoat before painting. All nuts, screws, washers and bolts shall be nickel or cadmium plated.

h) Full details of MDF and termination offered shall be supplied.

i) The MDF shall be equipped with high-speed multi-stage medium frequency surge protector with fast acting secondary clamp for each and every one of the line circuits irrespective of whether the termination is for an internal or an external line, unless the manufacturer can provide a 10 years unconditional guarantee against any damage due to any voltage surge on the line.

3.10 Telephone Outlet

a) Telephone outlets shall be of RJ-45 flush type, single and multi- outlet incorporating connector, clamp and grommet house in purpose made aluminum stove enamel finish boxes, complete with conduit knockouts. Telephone outlets shall be of type approved by TM

END OF SECTION

EIAT - INSPECTION AND TEST

CONTENTS

EIAT - INSPECTION AND TEST

1.0 GENERAL REQUIREMENTS

The whole of the Works covered by this Contract is subject to inspection and test by Sub-Contractor during manufacture, erection and on completion, but the approval of The Contractor or his representatives of the passing of any such inspection of test will not, however, prejudice the right of The Contractor or his representative to reject the plant if it does not comply with the Specification when erected, or to give complete satisfaction when erected, or to give complete satisfaction in service.

The costs of all tests and inspection at the place of manufacture and at Site including the provision of labour, materials, electricity, fuel, water, instruments, gauges, necessary for the tests and inspection shall be deemed to be included in the Contract Price.

Before any plant is packed or despatched, all tests called for in the Specification are to have been successfully carried out.

Sub-Contractor are to be given the option of witnessing all tests and adequate notice shall be given when any plant is ready for inspection or test to enable the necessary arrangements for attending the tests to be made. The Contract Price shall be deemed to include the cost of airfares, transport, subsistence and accommodation for Sub-Contractor to visit the factory of manufacturers and witness tests at manufacturer's works. Every facility shall be provided by Sub-Contractor to carry out the necessary inspection and test of the plant.

Detailed test formats and schedules shall be submitted by Sub-Contractor for approval at least 35 days before the scheduled tests or inspection.

1.1 Code and Standards

This section shall be designed and constructed in accordance with the latest revision of the following standards and the appropriate BS/IEC;

Standards	Document Titles
BS EN 60947-2:2017	Low-voltage switchgear and control gear. Circuit-breakers
BS EN 61439-2:2011	Low-voltage switchgear and control gear assemblies. Power switchgear and control gear assemblies
BS 7430	Code of practice for protective earthing of electrical installations

2.0 TESTS AT MANUFACTURER'S WORKS

Work tests are to include electrical and mechanical tests in accordance with the relevant B.S. or IEC unless otherwise specified. For plant not covered by any B.S. Specification, or specifically mentioned in this Specification, the tests shall be agreed with Sub-Contractor.

Should the plant or any portion thereof fail under test to give the required performance, further tests which are considered necessary shall be carried out by Sub-Contractorand the whole cost of the repeated tests shall be borne by Sub-Contractor.

2.1 Low Voltage Switchgear

The following tests shall be carried out at the manufacturer's works: -

Type tests to prove compliance with this specification and the requirements of BS EN 60947-2:2017and BS EN 61439-2:2011

a) Verification of temperature rise limits.

b) Verification of the dielectric properties.

c) Verification of the short circuit strength plus make and break tests for circuit breakers.

d) Verification of the continuity of the protective circuit.

e) Verification of clearances and creep age distances.

f) Verification of mechanical operation.

g) Verification of the degree of protection.

h) Verification of functionality.

Routine tests shall be carried out as listed in the British Standards and listed below: -

a) Injection tests to verify that all protection relays and equipment are suitable and are operating correctly.

b) Dielectric test at the full test voltage listed in the British Standard.

c) Verification of all electrical and mechanical operations and of correct functioning of interlocks, closing, tripping and inter-tripping of circuit breakers and alarm, instrumentation and signalling circuits.

d) Checking of protective measures and continuity of protective circuit.
e) High voltage test on cable boxes and associated equipment to verify that they will be capable of withstanding the first, and subsequent tests, on the cables to be connected thereto as noted in BS 6480 and BS 6346.

f) Verification of correct operation of all instruments and meters.

Certificates of rating to the appropriate British Standard issued by an approved Testing Authority will be accepted as documentary evidence that identical equipment has been type tested.

2.2 Conduits, Trunking and Cable Tray

All tests, to show compliance with the Specification and manufacturer's standard, shall be performed.

3.0 SITE TESTS DURING CONSTRUCTION

Sub-Contractor will be responsible for the submission of all plant in his supply for site inspection and tests as required. During the course of erection, The Contractor or his representative is to have full access for inspecting the progress of the work and checking the accuracy as may be required.

Sub-Contractor is to make available to the Contractor or his representative at site the necessary certified instruments, gauges and any other equipment necessary for checking the installation.

On completion of erection and before commencement of Tests on Completion, Sub-Contractor shall satisfy himself that the Works are entirely suitable for operational service and ready for the Tests on Completion. The Contractor or his representative shall be notified of such tests that Sub-Contractor may be carrying out prior to Tests on Completion.

4.0 TESTS ON COMPLETION

The following tests shall be carried out to the satisfaction of The Contractor or his representative on each completed section of the electrical installation and such other tests as may be required: -

(a) Soil resistivity tests and electrode and earthing system tests.

(b) Insulation resistance tests.

(c) Continuity tests.

(d) Tests to prove correct operation of interlocks, tripping and closing circuits, indications and integrations test with other equipment's or switchgear etc.

(e) Operation of all protective gear circuits by primary injection and system fault tests to check sensitivity and stability.

(f) Protective gear timing tests as may be necessary.

(g) Test operation of alarm devices.

(h) Rotational tests on all motors.

(i) Polarity tests to verify that single pole switches are installed in the phase or live conductor of each circuit and not in the neutral conductor.

(j) A test to verify the continuity of all conductors in every ring circuit, correct connections to terminals of all socket outlets and effective bonding to earth of each terminal and socket.

(k) Insulation resistance tests to and between conductors before connection of electrical equipment.

(l) Insulation of resistance tests of any electrical apparatus supplied and or erected under this or other Contracts before and after connecting such apparatus to the supply.

(m) Earth continuity tests for each final sub-circuit and the completed installation to ensure that the impedance of the earth fault loop is such as to permit compliance with the requirements of the current Edition of the IET Regulations for the Electrical Equipment of Buildings. Earth continuity tests shall be conducted using a Ferranti Phase-Earth Loop Impedance Tester (Model 2) or equivalent.

(n) Power factor tests for each final sub-circuit and the completed installation to ensure that the power factor for all electrical and mechanical load is above 0.90 lagging as to permit compliance with the requirements of Client. The Sub-Contractor will be fully liable for any non-compliance of this minimum power factor requirements.

4.1 Testing of Monitoring, Control and Alarm Cables

4.1.1 Continuity of cores

Insulation resistance between each core and all others bunched and connected to the screen and earthed. The acceptable minimum is 50 mega ohms resistance between conductors and from each conductor to grounded shield when tested at not less than 500V DC.

To prove that there are no crosses in core numberings in joints or in cable.

The resistance of each core. The minimum acceptable value of insulation resistance shall be that stated by Sub-Contractor for works tests.

Ringing out from box to box to check that all core terminations are numbered off in the same physical position in each box, and that jointing has been strictly carried out on a number to number basis.

4.2 Testing of Low Voltage Cable

The minimum tests to be carried out on each completed section of the installation shall be as follows: -

a) Phasing out tests

b) Insulation resistance test

c) Continuity tests

d) Phase rotation tests on completion of the installation and erection of switchgear with the system alive. Phase rotation shall be standard.

e) Tests shall be carried out to prove that all switches in lighting circuits, the switch and live pin in socket outlets and all breakers are in the live conductor.

In addition, the complete installation shall be subjected to and shall satisfactorily pass all tests prescribed in the current edition of the IET Regulations except that for all PVC insulated cables and MICC cables, the insulation resistance shall not be less than 100 mega ohms when tested using a 500V megger.

4.3 Earth Electrode Resistance and Earth Continuity Resistance Tests

These tests shall be carried out in accordance with British Standard Code of Practice BS 7430, prior to commissioning the whole or part of the installation.

4.4 Low Voltage Switchgear

The minimum tests to be carried out on each completed section of the installation shall be as follows: -

a) Injection tests to verify that all protection relays and equipment are suitable and are operating correctly.

b) Dielectric test at the full test voltage listed in the British Standard.

c) Verification of all electrical and mechanical operations and of correct functioning of interlocks, closing tripping and inter-tripping of circuit breakers and alarm, instrumentation and signalling circuits.

d) Checking of protective measures and continuity of protective circuit.

4.5 Bomba Testing

On successful completion of the Tests on Completion, Sub-Contractor shall arrange for the inspection and testing by Bomba. All necessary submission of information, drawings, catalogues, back-up calculation, and testing requirement as required by Bomba shall be carried out. All costs incurred in carrying out the Bomba Tests shall be deemed to be included in the Contract Price.

5.0 TESTING CERTIFICATES AND RECORDS

Certificates of tests shall be completed when the tests are carried out and Sub-Contractor shall issue three copies of all certificates to The Contractor or his representative within seven days after completion of the tests.

Triplicate sets of all principal test records and test certificates are to be supplied for all tests carried out in accordance with the provisions of this Contract. These test records and certificates are to be supplied for all tests, whether or not The Contractor or his representative has witnessed them. The information given on such test certificates is to be sufficient to identify the material or equipment to which the certificate refers and should also bear the Contract reference and heading.

6.0 RELIABILITY TESTS

Upon successful completion of the Tests on Completion and when Sub-Contractor considers that the Works are ready for operational service, and providing The Contractor or his representative agree that the Works are ready for operational service, each section of the installation will be required to operate under the working conditions, either continuously or intermittently as may be convenient, without failure or interruption of any kind for a period of not less than 30 days.

The plant will be operated by the maintenance staff during the reliability test period, but Sub-Contractors will be allowed to make any minor adjustments in the presence of the maintenance staff, which may be necessary, provided that such adjustments which may be necessary do not in any way interfere with, or prevent operational use by The Contractor or his representative.

Should any failure or interruption occur in any portion of the works, due to, or arising from faulty design, materials or workmanship or due to incorrect erection but not otherwise sufficient to prevent the full operational use of the works, the reliability test period of 30 days shall recommence after Sub-Contractor has remedied the cause of the defect.

The onus of providing that any defect is due to causes other than those referred to in the preceding paragraph will lie with Sub-Contractor.

On satisfactory completion of the reliability test period, the Architect will issue the Certificate of Practical Completion to Sub-Contractor duly back-dated.

During the whole of the reliability period Sub-Contractor is to be represented on site by competent foremen and other operators who shall be available at site during normal daytime working hours, and any other hours necessary for the satisfactory operation of the works. Sub-Contractor's operators are to continue to instruct the operating personnel in the correct operation of the plant where necessary.

END OF SECTION

ETCH - TESTING, COMMISSIONING AND HANDOVER

CONTENTS

ETCH - TESTING, COMMISSIONING AND HAND OVER

1.0 GENERAL

The Sub-Contractor shall carry out all testing and commissioning necessary for the safe, reliable and satisfactory operation of the system and equipment installed.

The Works shall be tested and commissioned in accordance with manufacturer's instructions, IET wiring regulations, local Authorities requirements, Government requirements, relevant international standard and this Specification.

At least two months prior to testing or commissioning any system, the Sub-Contractor shall furnish the following information for each system or process to the Contractor or his representative for review.

a) Testing procedure and details as well as the relevant report forms to the Contractor or his representative for approval.
b) Type of instruments to be used
c) Manufacturer of instruments
d) Calibration methods for instruments
e) Operating instructions for instruments
f) Accuracy and tolerances of instruments
g) Complete schedule and programme of all testing and commissioning activities

The Sub-Contractor shall employ a team of competent and experienced personnel to carry out all testing and commissioning works. If it is the opinion of the Contractor or his representative that the testing and commissioning are not properly executed by the Sub-Contractor's own staff, the Sub-Contractor shall employ a qualified independent Testing and Commissioning Specialist to carry out this part of the Works, when directed by the Contractor or his representative. The cost of employing this Testing and Commissioning Specialist shall be borne by the Sub-Contractor.

The Sub-Contractor shall provide all instruments and labour necessary for testing and commissioning of the entire installation.

All instruments shall have been recalibrated within six months of the start of commissioning or testing. Calibration of all instruments shall be certified by the instrument manufacturers or an approved calibration agency.

Should the results of any test show that any plant, system or equipment fails to perform to the efficiencies or duties as given in this Specification, the Sub-Contractor shall adjust, modify and if necessary replace the equipment without further payment in order that the required performances shall be obtained.

Should it be necessary for the Sub-Contractor to modify or replace any item of plant as described above, he shall be responsible for the cost for making good of any damage or deterioration to the building or other services consequent on such modifications.

All equipment site testing and commissioning shall be carried out by manufacturer's qualified engineers.

2.0 FACTORY TESTS

The following items of equipment shall be tested at the manufacturer's works or elsewhere as appropriate prior to installation. In all cases, test certificates shall be submitted in triplicate.

2.1 LV Switchboard

Type test Certificates indicate short circuit capacity and temperature rise

Factory Tests Report on the unit.

2.2 Standby Generator Set

Type Test Certificate

Factory Tests Report on the unit

2.3 Fuel Storage Tank

Hydraulic Test Report endorsed by Sub-Contractor's Mechanical Professional Engineer.

2.4 HV Switch Board

Site Tests Report on the unit

2.5 HV/LV Transformer

Site Tests Report on the unit

2.6 Lighting

Factory Tests Report on the unit. All illumination reports for every individual space or rooms. All relevant certifications and product catalogues are to be provided together with the test reports to The Contractor or his representative for approval prior to installation.

Sub-Contractor shall submit to The Contractor or his representative the catalogues, certifications (including SIRIM and IEC/BS compliance) and simulation reports for all space and rooms. Sub-Contractor shall make available to DBC or his representative the catalogues, certifications (including SIRIM and IEC/BS compliance) and simulation reports for individuals' lamp and fittings.

All tests, to show compliance with the specifications and manufacturer's standards shall be performed.

2.7 Power Factor

Power factor test on all electrical and mechanical equipment.

3.0 SITE TESTING AND COMMISSIONING

3.1 Execution of Tests

The plant shall be inspected and tested during and after installation on site as set out below for compliance with the performances, and ratings as specified.

All tests shall be witnessed by the Contractor or his representative at site with at least seven days' notice given prior to any test.

All tests shall be executed and, if not satisfactory, shall be repeated to the satisfaction of the Contractor or his representative at no extra cost.

Infrared Thermoelectric Detection to all HV and LV Main Switch Board, Transformer, Generator and Busbar Trunking to locate any hot spot or loose termination. The test shall be performed by specialist Tester completed with conclusive report to record the working condition of the installation and Termination.

At the appropriate stages of the installation, inspection and testing prior to the energizing of equipment, insulation tests shall be made and recorded.

Operational tests of all electrical equipment in proper staged phases shall be made and recorded prior to energizing. For example, the battery charger and batteries shall be checked prior to furnishing the DC control power for the circuit breakers. The circuit breaker control shall be operationally checked for all local control, including testing up to interface terminal points for signals and control interconnection to other system or installation, prior to carrying out operational tests of the circuit breaker.

The Sub-Contractor shall develop a complete and detailed plan for the site testing of the power supply systems beginning with the incoming breakers and following a logical plan which will allow energization of the system in a safe and secure manner and to interface and co-ordinate with the other electrical and mechanical installations.

a) The Sub-Contractor shall provide his own equipment for testing and check the installation to ensure that it complies with drawing and specification and the supply authority's requirements, including the preliminary polarity test and phasing of electrical mains.
b) Test results shall be recorded and certified by Sub-Contractor's Licensed Electrical Worker. Two (2) copies of such report shall be submitted to the Contractor or his representative prior to the joint testing.

The Sub-Contractor shall be responsible for the surveillance and security of the power systems including padlocking or otherwise maintaining control of the power supply, padlocking of switchgear and circuit breaker units, distribution switchboards, etc. throughout all energization stages of the installation. The Sub-Contractor shall co-ordinate with the other specialist Sub-

Contractor s to assure no downstream cables or other electrical equipment is energized before tested and before other specialist Sub-Contractor s' facilities are ready and secure. The Sub-Contractor 's responsibility for surveillance and security of the system shall remain in force for each part of the system until such a time that the complete installation is certified complete by the Sub-Contractor in writing.

Precautionary measures shall be taken during testing and the method of tests shall be such that no danger to persons or property can occur even if the circuit being tested is defective.

Sub-Contractor shall demonstrate and certify on site to prove that the power factor is above 0.85 when operating at any load.

3.2 Site Tests

Site Test shall show, inter alia, that:

a) All equipment, cabling, distribution, etc. is electrically and mechanically safe.
b) All interlocks, isolators and door cover securing mechanisms are properly fitted and adjusted.
c) All exposed metal work is properly bonded and earthed in accordance statutory requirements and that all connections and points required to be earthed for safety and satisfactory operation are properly earthed in accordance with the manufacturer's requirements.
d) All cables, cores and terminations are properly marked off, secured, properly supported and correctly identified and coloured.
e) All phases, polarities, natural and common connections are correctly switched as required, that power is correctly available at all points and that voltage and frequency at all equipment are correct and in accordance with requirements for correct working.
f) All supplies are properly fused, or otherwise protected to give satisfactory discrimination and safe disconnection under fault conditions.
g) All contact is properly aligned and not subject to. excessive wear and erosion.
h) All protective covers are properly fitted, all warning and designating labels are correct and in position and the inside of all boxes and cubicles are clean and free of ‘swarf’ and cable strippings.
i) Batteries, if provided, are properly ventilated, installed, connected and fitted, and that battery chargers are working correctly.
j) Insulation resistance of all cabling and equipment is not less than that required by relevant standard and code of practice.
k) All instruments and meters are energized with correct polarity and working properly.
l) All fault indications and alarms are working correctly.
m) All essential equipment fed from battery systems continue to function correctly and without disturbance during all supply failure, restoration and standby sequences.
n) In addition to all operational tests required for satisfactory completion. The operation of all interlocks, sequences and protection not utilized in normal operations shall be checked to the satisfaction of the Sub-Contractor.

3.3 Functional Tests

Functional test for the system shall be conducted for performance, safety, reliability, maintainability and for compliance with the design requirements. These tests shall be performed progressively on site in accordance with the Contract programme to verify that the complete installation will meet the requirement of this specification. The list provided below is an indicative minimum requirement of the tests:

a) Check correct CT ratio and polarity and correct operation of all protective gear by primary tests and system fault tests to check sensitivity and stability.
b) Secondary current injection tests for accuracy of relay operations. Protective gear timing tests as may be necessary.
c) Rotational tests on all motors.
d) Battery tests on specific gravity, correct output voltage and proper functioning of the charging equipment etc.
e) Tests to prove correct operation of all interlocks, tripping and closing circuits, alarm indications, etc including operation in conjunction with the standby generator for emergency operation of lifts, etc.
f) Phasing tests.
g) Power factor test.

HV Switch Board. Transformer and HV cable

a) HV Switchboard
   (i) Injection Test
   (ii) Insulation Test

b) Transformer
   (i) Insulation Resistance Test (Between the phases and earth, between phases and between HV & LV phases)
   (ii) Polarization Index (PI) test.
   (iii) Tripping and alarm circuit test
   (iv) Visual check of Tap changing mechanism.
   (v) Voltage ratio check on each tapping.
   (vi) Buchholz relay check

c) HV Cable
   (i) 5 kV Megger test

d) LV Switchboard
   (i) General inspection
   (ii) Mechanical tests
   (iii) Continuity and dielectric tests
   (iv) Secondary injection test to re-calibrate all measuring, protect and control circuits and associated components
   (v) Phase sequence tests on each outgoing units
   (vi) Functional checks, especially on the controlling devices

e) Cables
   (i) Continuity test
   (ii) Insulation resistance test and
   (iii) Phasing test

f) Standby Generator Set
   (i) Series of test starts and checks on ability to take up the load within the specified time
   (ii) Check that speed variation is within specified limits
   (iii) Voltage regulation test
   (iv) Functional tests of all plant protection features and alarms
   (v) Temperature rise test
   (vi) Noise level measurement
   (vii) Insulation resistance test
   (viii) Building essential load test and

g) Hydraulic Tests
   (i) Hydraulic test of 70 kPa for bulk tank for not less than 2 hours
   (ii) Hydraulic test of 70 kPa for pipe works, valves and fittings for not less than 2 hours.

h) LV Power Distribution System
   The following items, where relevant, shall be tested in the sequence indicated:
   (i) Continuity of ring final circuit conductors
   (ii) Continuity of protective conductors, including main and supplementary equipment bonding
   (iii) Earth electrode resistance
   (iv) Insulation resistance
   (v) Insulation of site-built assemblies
   (vi) Protection by electrical separation
   (vii) Polarity
   (viii) Earth fault loop impedance
   (ix) Function of all items of equipment and
   (x) Power Factor

i) Lighting
   (i) Illuminance / luminance measurements for normal, emergency and battery lightings
   (ii) Illuminance / luminance measurement for battery lights at the end of 2-hour operation
   (iii) Test to establish correct operation of switching control
   (iv) Insulation resistance tests to earth and between conductors before and after fitting of lamps and
   (v) Measurement of leakage current when directed by the Sub-Contractor.

j) Lightning Protection System
   (i) Continuity between air and earth terminations; and
   (ii) Earth electrode resistance.

k) UPS
   (i) Full Test to Manufacturer Recommended Procedures

l) Extra Low Voltage System
   (i) Full Functional Test to Manufacturer Recommended Procedure

m) Earthing
   (i) Site Tests
   - Visual Inspection
   - Condition and size of conductor and accessories.
   - Check correct fastening of conductors and interval of clips.
   - Completeness, tightness, material of earthing joints/connections and correct type of clamps/joints and connections.
   - Check exothermic welds.
   - Protection against mechanical damage to the conductor.
   - Check provision and correctness of labels.
   - Protection against corrosion.

   (ii) Earth Resistance Tests
   - The Sub-Contractor shall carry out tests to demonstrate to the Contractor or his representative that the earth resistance of the earthing system and the individual earth inspection chamber/pit shall not be greater than (≤) 1 ohms.
   - Earth resistance of each individual earthing systems and the complete earthing system shall be measured using approved and calibrated earth resistance test unit.

   (iii) Continuity Test
   The Sub-Contractor shall carry out tests to demonstrate to the Contractor or his representative continuity of all connections of the earthing system.

4.0 AUTHORITIES TEST AND INSPECTION

The Sub-Contractor shall engage sufficient qualified and experienced site staff to execute the works. Registered and licensed tradespersons shall be employed to supervise the works if necessary.

The services of Licensed Electrical Engineer, Professional Engineers (Mechanical and Electrical) and other statutory licensed workers engineers shall be engaged to assume full responsibilities for all engineering matters including engineering design, submission to Authorities, installation and switching. These personnel shall be available to attend meetings, discussions, inspections, and the like as required by the Contractor or his representative and Authorities. Upon completion of the Contract works, the Licensed Electrical Engineer and Professional Engineers shall furnish Completion and Inspection Certificates with the same format as required by the respective authority for the respective parts of the works to the Contractor or his representative to certify that all the works are in full compliance with the Specification and Drawings.

5.0 FINAL ADJUSTMENTS AND COMMISSIONING

a) When the entire installation works are completed and all the above checking and testing have been properly carried out, the Sub-Contractor shall set to work, regulate and calibrate the entire installation. Particular attention shall be paid to the following:

i) All valves, traps, dampers, switches, controls, etc. are regulated to operate properly in accordance with the specified performance. All valves shall be able to be shut off totally at the maximum anticipated system working pressure.
ii) All equipment are silent and meeting the specified noise and vibration levels.
iii) All instruments are correctly calibrated and read accurately.
iv) All air-handling and ventilation plants are operated properly: and are able to deliver the correct air-flow rate to each individual space.
v) All control systems are functioning correctly and are properly sequenced, interlocked, and interfaced with other services.
vi) All major plant to be fully commissioned by the respective Manufacturer's qualified field testing and commissioning engineers.

b) The Sub-Contractor shall be aware that the commissioning may need to be carried out after the issuance of Certificate of Practical Completion and after normally office hours, as required by the Contractor or his representative.

6.0 HANDING OVER

a) The following procedures shall be adopted prior to handing over the installation:
i) All preliminary testing, checking, adjusting and balancing of the installation shall be carried out before forwarding notification that the installation is considered to have reached Practical Completion.
ii) After inspection, and when the Contractor or his representative is satisfied and agrees that the installation is ready for handing over to the Client the plant shall be finally commissioned and Installation Manuals together with as-built drawings shall be provided as specified.

b) Certificate of Practical Completion will be issued only after the plant has been inspected and approved and the above requirements fulfilled.

END OF SECTION

CONCRETE WORKS

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CONCRETE WORKS

1.0 DESCRIPTION

This work shall consist of the construction of all structures or parts of structures to be composed of Portland cement concrete with or without steel reinforcement, except for reinforced concrete pipe culverts. Concrete cast using blended cement such as Portland cement with ground granulated blast furnace slag shall also be classified under this work. The work shall be carried out all in accordance with this Specification and the lines, levels, grades, dimensions and cross-sections shown on the Drawings.

The contractor to submit a list of supplies from whom he wishes to purchase the materials necessary for the execution of works, sampling, submission of test certificates, etc.

2.0 MATERIALS

2.1 Cement

The cement to be used throughout the work shall be Portland cement obtained from an approved manufacturer. The source of supply of cement for concrete in the guideway structures to be kept constant for each structure. Single source of cement for use in concrete for the same visible structural unit (for instance, single pier, single portal or single viaduct span) is required to avoid variation in concrete colour tone. The cement shall be described under one of the following headings: -

(a) Ordinary Portland Cement

The cement shall comply with MS 522.

(b) Rapid Hardening Portland Cement

The cement shall comply with MS 522.

(c) Moderate Sulphate Resisting Portland Cement

The cement shall comply with MS 1037 or BS 4027.

(d) Sulphate Resisting Portland Cement

The cement shall comply with MS 1037 or BS 4027.

(e) Portland Slag Cement/Portland Blastfurnace Cement

The cement shall comply with MS 1389 or BS 146

(f) High Slag Blastfurnace Cement

The cement shall comply with MS 1388 or BS 146

(g) Portland Pulverised-fuel Ash Cement

The cement shall comply with MS 1277

(h) Pulverised-fuel Ash Cement

The cement shall comply with BS 3892 Part 1

(i) Ground Granulated Blastfurnace Slag Cement

The cement shall comply with BS 6699

Manufacturer's certificates of test will, in general, be accepted as proof of soundness. Additional tests shall be carried out on any cement which appears to have deteriorated through age, damage to containers, improper storage or any other reason. In any event, the batch of cement which has been sampled and tested and found not to have complied with the requirements shall be rejected and removed from the Site.

2.1.1 Transportation and Storage

The cement shall be transported to the Site in covered vehicles adequately protected against water. It shall be stored in a weatherproof cement store and shall be taken for use in the Works in the order of its delivery into the store. Cement delivered in bulk shall be stored in silos of an approved design. The contractor has to submit particulars of the silo locations and other details of the intended storage arrangements for the approval of the engineer.

2.2 Aggregates

Aggregates shall be naturally occurring sand, gravel or stone, crushed or uncrushed except as otherwise specified, and shall comply with MS 29. They shall be hard, strong, durable and clean. They shall be free from adhering coatings and shall not contain any harmful material in sufficient quantity so as to affect adversely the strength, durability and impermeability of the concrete.

Marine aggregates shall not be used unless otherwise specified.

(a) Coarse Aggregate

Coarse aggregate shall comply with MS 29.

(b) Fine Aggregate

Fine aggregate shall comply with MS 29. If it is found necessary, the fine aggregate shall be washed and screeded.

2.2.1 Grading

2.2.1.1 Coarse Aggregate

The grading of coarse aggregate shall be analyzed as described in MS 30 and shall be within the limits given in Table 1.

TABLE 1 - COARSE AGGREGATE

Sieve Size (mm)	Graded Aggregate Percentage by mass passing BS Sieve for Nominal Size		
	40 mm to 5 mm (a)	20 mm to 5 mm (b)	14 mm to 5 mm (c)
50	100	-	-
37.5	90 – 100	100	-
20	35 – 70	90 – 100	100
14	25 – 55	40 – 80	90 – 100
10	10 – 40	30 – 60	50 – 85
5	0 – 5	0 – 10	0 – 10
2.36	-	-	-

Notes:

(i) Type (a) aggregate shall not be used in thin members and / or where the reinforcement is congested. Type (c) aggregate shall be used only when specifically required to be used. Where not specified, type (b) aggregate shall be used.

(ii) The maximum sizes of coarse aggregates for various grades of concrete shall not exceed the limits stated in Table 6.

2.2.1.2 Fine Aggregate

The grading of fine aggregate shall be analyzed as described in MS 30 and shall be within the limits of one of the grading zones given in Table 2.

TABLE 2 - FINE AGGREGATE

BS 410:2000 Test Sieve	Percentage by Weight Passing BS Sieve			
	Grading Zone 1	Grading Zone 2	Grading Zone 3	Grading Zone 4
(mm)				
10.0	100	100	100	100
5.0	90 – 100	90 – 100	90 – 100	95 – 100
2.36	60 – 95	75 – 100	85 – 100	95 – 100
1.18	30 – 70	55 – 90	75 – 100	90 - 100
(microns)				
600	15 – 34	35 – 59	60 – 70	80 – 100
300	5 – 20	8 – 30	12 – 40	15 – 50
150	0 - 10	0 - 10	0 - 10	0 - 15

2.2.2 Sampling and Testing of Aggregates

Samples of the fine and coarse aggregates approved by the engineer shall be kept on Site, and shall give a fair indication of the general quality of the aggregates for comparison with the aggregates delivered during the course of the work. Tests shall be carried out on samples of the latter taken at intervals as specified in Table 3 each month or per 200m^3 whichever is more frequent. The method of sampling and testing shall be in accordance with MS 30 and other standards as specified in Table 3. Any batch of aggregate rejected by the engineer shall be removed from the Site.

TABLE 3 – TESTING OF AGGREGATES

Properties	Test Methods	Limits
Grading	MS 30	Table 1 and Table 2
Elongation	MS 30	Not exceeding 30%
Flakiness Index	MS 30	Not exceeding 25%
Water Absorption	MS 30	Not exceeding 1.5%
Clay, Silt and Dust	MS 30	Not exceeding 2%
Organic Impurities	MS 30	Not exceeding 0.4%
Aggregate Crushing Value	MS 30	Not exceeding 20%
Soundness Test (Sodium Sulphate)	AASHTO Test	Loss not exceeding 12%
Chloride Content	BS 812: Part 4	Not exceeding 0.06% by mass of chloride ion of combined aggregate
Sulphate Content	BS 1377: Test 9	Not exceeding 0.4% by weight of SO_3

2.2.3 Storage of Aggregates

Separate storage facilities with adequate provision for drainage shall be provided for each different size of aggregate used.

Aggregate shall be handled and stored so as to avoid segregation and contamination.

2.3 Water

Water shall comply with the requirements of MS 28. It shall be clean and free from harmful matter. The contractor shall make adequate arrangements to supply and store sufficient water at the Site for use in mixing and curing concrete. All costs for installing and maintaining the supply shall be borne by the contractor.

2.4 Admixtures

Suitable admixtures may be used in concrete mixes with the prior approval of the engineer and the following to be adhered to:

a) The contractor shall submit samples of the admixture to the engineer for approval at least thirty five (35) days prior to the date of commencement of construction of the particular structure.

b) Approved admixtures shall be introduced into the mix at the time of adding water by a method ensuring an even and accurate dispersion throughout the mix.

All requirements for sampling, acceptance tests, uniformity tests, independent tests, chloride content, and information to be provided by manufacturer, compliance and storage certificates and marking shall be in accordance with MS 922: Part 1.

All admixtures shall be used strictly in accordance with manufacturer's instructions.

Before allowing the admixture to be used in the work, relevant tests based on trial mixes shall be carried out. The trial mix shall be made using job-site materials and under job-site conditions. A control mix shall be made using a conventional trial mix that is without using the admixture, to determine the water/cement ratio and mix proportions required to give the specified strength with the required slump. Using the same mix proportions as in the control mix, a test shall be prepared using the recommended dosage of the admixture. The results of relevant tests obtained from the control mix and test mix shall be compared. The engineer may allow the use of the admixture only when the results are found to be satisfactory and comparable to the effects as claimed by the manufacturer. Table 4 of admixture acceptance test requirements shall be complied with.

Admixtures which contain calcium chloride or calcium formate as the active constituents shall not be used for structural concrete containing reinforcement, prestressing tendons or other embedded metal.

TABLE 4 – ADMIXTURE ACCEPTANCE TEST REQUIREMENTS

Category Admixture	Water Reduction	Stiffening Time: Time from completion of mixing to reach a resistance to penetration of:-			Minimum Strength as a percentage of the control mix:-		Age	Length change, max. shrinkage	
		0.5 N/mm	3.5 N/mm	27.5 N/mm	Compressive	Flexural		% of control	Increase
Type 1 : Accelerating	-	More than 1h.	Within 1 h to 3 hrs earlier than control mix	At least 1 h earlier than control mix	125 125 100 100	110 110 110 90	24 hrs 3 days 7 days 28 days	135	0.6
Type 2 : Retarding	-	At least 1h later than control mix	Within 1h to 3 hrs later than control mix	Not more than 3 hrs later than control mix	90 90 95	90 90 90	3 days 7 days 28 days	135	0.1
Type 3 : Normal water reducing	At least 5%	Within ± 1 h of control mix	Within ± 1 h of control mix	Within ± 1 h of control mix	110 110 110	100 100 100	3 days 7 days 28 days	135	0.1
Type 4: Accelerating water reducing	At least 5%	More than 1 h	Within 1 h to 3 hrs earlier than control mix	At least 1 h earlier than control mix	125 125 100 100	- 110 100 100	3 days 7 days 28 days	135	0.1
Type 5: Retarding water reducing	At least 5%	At least 1 h later than control mix	Within 1 hr to 3 hrs later than control mix	Not more than 3 hrs later than control mix	110 110 110	100 100 100	3 days 7 days 28 days	135	0.1

3.0 CLASSIFICATION OF CONCRETE MIXES

The concrete mixes shall be classified as: -

(a) Prescribed Mix

The contractor shall provide concrete that contains constituents in the specified proportions.

(b) Designed Mix

The contractor shall select the mix proportions and unless otherwise specified, the workability, in order to satisfy the strength and other requirements of the Specification.

3.1 Characteristic Strength of Concrete

The grades of concrete and the respective characteristic strength to be used in the work shall be as noted in the Drawings and given in Table 5.

TABLE 5 – GRADES OF CONCRETE

Grade	15	30	35	35A	40	45	50	60
Characteristic Strength of cube at 28 days in N/mm²	15.0 (mass concrete)	30.0	35.0	35.0	40.0	45.0	50.0	60.0

3.2 Requirements for Prescribed Mixes

Unless otherwise specified, the concrete mix shall be as detailed in Table 6 which shows the minimum weight of cement, in kilograms, to produce approximately one (1) cubic metre of fully compacted concrete.

TABLE 6 - PRESCRIBED MIXES FOR GENERAL USE

	Nominal max. size of aggregate (mm)	40		20		14		10	
Concrete	Workability	Medium	High	Medium	High	Medium	High	Medium	High
Grade	Slump Limits (mm)	50 to 100	100 to 150	25 to 75	75 to 125	10 to 50	50 to 100	10 to 25	25 to 50
15	Cement (kg)	250	270	280	310	-	-	-	-
	Total aggregate (kg)	1850	1800	1800	1750	-	-	-	-
	Fine aggregate (%)	30 to 45	30 to 45	35 to 50	35 to 50	-	-	-	-
30	Cement (kg)	370	390	400	430	430	470	460	510
	Total aggregate (kg)	1750	1750	1700	1650	1700	1600	1650	1550
	Sand*								
	Zone 1 (%)	35	40	40	45	45	50	50	55
	Zone 2 (%)	30	35	35	40	40	45	45	50
	Zone 3 (%)	30	30	30	35	35	40	40	45

In Table 6 above:

i) Sand is defined as fine aggregate resulting from the natural disintegration of rock.

ii) The minimum cement content is for concrete structures exposed to moderate conditions of exposure and shall be overridden by the requirements of the relevant specific Sections.

iii) In any circumstance, the maximum cement content shall not exceed 550 kg/m³ of finished concrete.

For concrete grades 35 to 60, cement content, aggregate requirement and workability shall be evaluated by establishing design mixes.

3.3 Requirements for Designed Mixes

3.3.1 Target Mean Strength

The concrete mix shall be designed to have at least the required minimum cement content and to have a target mean strength greater than the required characteristic strength by at least the current margin.

3.3.2 Current Margin

The current margin for each particular type of concrete shall be determined by the contractor and shall be taken as the lesser of: -

a. 1.64 times the standard deviation of cube tests on at least one hundred (100) separate batches of concrete of nominally similar proportion of similar materials and produced over a period not exceeding twelve (twelve (12) months by the same plant under similar supervision, but not less than one sixth of the characteristic strength for concrete up to grade 15 or 3.75 N/mm² for concrete of grade 20 or above;

b. 1.64 times the standard deviation of cube tests on at least forty (40) separate batches of concrete of nominally similar proportions of similar materials and produced over a period exceeding five (5) days but not exceeding six (6) months by the same plant under similar supervision, but not less than one third of the characteristic strength of concrete up to grade 15 or 7.5 N/mm² for concrete of grade 20 or above.

Where there are insufficient data to satisfy (i) or (ii) above, the margin for the initial mix design shall be taken as two thirds of the characteristic strength for concrete up to grade 15 and 15 N/mm² for concrete of grade 30 or above. This margin shall be used as the current margin only until sufficient data are available to satisfy (i) or (ii) above. However, subject to the approval of the engineer, when the specified characteristic strength approaches the maximum possible strength of concrete made with a particular aggregate, a smaller margin not less than 5 N/mm² for concrete of grade 15 or 7.5 N/mm² for concrete of grade 30 or above may be used for the initial mix design.

3.3.3 Suitability of Proposed Mix Proportions

The contractor shall submit for the approval of the engineer, prior to the supply of any designed mix, the following:-

(i) the nature and source of each material;

(ii) appropriate existing data as evidence of satisfactory previous performance for target mean strength, current margin, workability and water/cement ratio; OR full details of tests on trial mixes carried out in accordance with Sub-section 3.3.4;

(iii) the proposed quantities of each material per cubic metre of fully compacted concrete.

3.3.4 Trial Mixes

The contractor shall give notice to enable the engineer to be present at the making of trial mixes and preliminary testing of the cubes. The contractor shall prepare trial mixes, using samples of approved material typical of those he proposes to use in the Works, for all grades to the satisfaction of the engineer prior to commencement of concreting.

Sampling and testing procedures shall be in accordance with MS 26. Three (3) separate batches of concrete shall be made. The workability of each of the three (3) trial batches determined by means of the slump test, compacting factor test or vebe consistometer test in accordance with MS 26, shall be appropriate to the proposed uses and methods of placing and compaction of the mix. Six (6) cubes shall be made from each batch. Three (3) from each set of six (6) shall be tested at an age of seven (7) days and three (3) at an age of twenty eight (28) days. The average strength of the nine (9) cubes tested at twenty eight (28) days shall exceed the specified characteristic strength by the current margin minus 3.5 N/mm². The approved trial mix shall then be designated as the "designed mix" and its corresponding workability as the "designed workability".

During production, the engineer may require additional trial mixes to be made before a substantial change is made in the materials or in the proportion of the materials to be used. Trial mixes need not be carried out when adjustments are being made to the mix proportions in accordance with Sub-section 3.3.5.

3.3.5 Control of Strength of Designed Mixes

(a) Adjustment to Mix Proportions

Adjustment to mix proportions shall be made in order to minimize the variability of strength and to maintain the target mean strength. The specified limits of minimum cement content and maximum water/cement ratio shall be maintained. Changes in cement have to be declared. Such adjustment shall not be taken to imply any changes in the current margin.

(b) Change of Current Margin

A change in the current margin used for judging compliance with specified characteristic strengths becomes appropriate when the results of a sufficiently large number of tests show that the previously established margin is significantly too large or too small.

Recalculation of the margin shall be carried out in accordance with Sub-section 3.3.2. Although a recalculated margin is almost certain to differ numerically from the previous value, the adoption of the recalculated value will not generally be justified if the two (2) values differ by less than 18% when based on tests of forty (40) separate batches or less than 11% when based on tests of one hundred (100) separate batches, or less than 5% when based on tests on five hundred (500) separate batches.

On the adoption of a recalculated margin it shall become the current margin for the judgement of compliance with the specified characteristic strength of concrete produced subsequent to the change.

3.4 Requirements for Concrete

3.4.1 Workability

The workability of the fresh concrete shall be such that the concrete is suitable for the conditions of handling and placing so that after compaction, it surrounds all reinforcement, tendons and ducts and completely fills the formwork.

Workability of the concrete shall be within one of the following tolerances: -

(i) Slump

± 25 mm or ± one-third of the "designed workability", whichever is the greater.

(ii) Compacting Factor

± 0.03 where the "design workability" is 0.9 or more.
± 0.04 where the "design workability" is between 0.8 and 0.9.

± 0.05 where the "design workability" is 0.8 or less.

(iii) Vebe

± 3 seconds or ± one-fifth of the "design workability" whichever is less.

3.4.2 Concrete Grade

The grade of concrete to be used in the Works shall be as stated on the Drawings and in the Bill of Quantities.

(Concrete grade shall be designated as GRADE X/Y where "X" is the numerical value of the characteristic strength in N/mm² as determined from test cubes at twenty-eight (28) days, and "Y" is the nominal size of aggregate in mm. For a prescribed mix, a suffix "P" shall be added after "X").

3.4.3 Minimum Cement Content

The minimum cement content shall be in accordance with Table 7 unless otherwise shown on the Drawings. For Concrete Grade 35A, the minimum cement content shall be 325 kg/m³ and maximum water/cement ratio shall be 0.55.

3.4.4 Maximum Cement Content

a) Concrete mixes shall be designed by the contractor for each grade of concrete as shown in the table below:

TABLE 7 - MINIMUM CEMENT CONTENT AND MAXIMUM FREE WATER/CEMENT RATIO FOR DESIGNED MIX

Concrete Grade	Cube Strength						
(N/mm^2)	25	30	35	40	45	50	60
Min. 7-day Strength (N/mm^2)	16	20	24	28	32	36	45
Min. Cement Content (kg/m^3)	310	325	350	375	400	425	550
Max. Cement Content (kg/m^3)	550	550	550	550	550	550	600
Max. Water / Cement Ratio	0.55	0.55	0.50	0.45	0.45	0.40	0.3
Max. Nominal Size of Coarse Aggregate (mm)	20	20	20	20	20	20	20

For concrete grade C55 and above, the contractor shall submit to the engineer and his representative for approval the design mix requirements.

b) A mix design for a special concrete grade shall conform to the foregoing requirement in all respect. In particular, the contractor shall price his concrete rates for full compliance with the minimum cement content specified for each concrete grade to meet durability requirements. A mix design which does not comply with the minimum cement content shall not be approved for use in the works, notwithstanding its compressive strength results.

3.4.5 Total Chloride Content

The total chloride content of the concrete mix arising from the aggregate or any other source shall not in any circumstances exceed the limits in Table 8 expressed as a percentage relationship between chloride ions and mass of cement in the mix.

Tests shall be carried out in accordance with BS 1881:1970-1990 for each grade of concrete, to demonstrate that these limits are not exceeded.

TABLE 8 – MAXIMUM TOTAL CHLORIDE CONTENT

Type of Concrete	Maximum Total Percentage of Chloride Ion by Mass of Cement
Reinforced Concrete made with cement complying with MS 522 Plain Concrete containing embedded metal and made with cement complying with MS 522	0.35 for 95% of test results, with no results greater than 0.50 0.35 for 95% of test results, with no results greater than 0.50
Concrete made with cement complying with MS 1037:1986 or BS 4027	0.2
Prestressed Concrete and Structural Concrete that is steam cured	0.1

Notes:

(i) % Chloride ions x 1.648 = % equivalent sodium chloride
(ii) % Chloride ions x 1.56 = % equivalent anhydrous calcium chloride

3.4.6 Maximum Sulphate Content

The total estimated sulphate content of any mix, including that present in the cement shall not exceed 4.0% by weight of cement in the mix. Tests shall be carried out in accordance with BS 1881 for each grade of concrete to demonstrate that these limits are not exceeded.

3.4.7 Cement Additives

PFA with or without microsilica shall be added to the mix to achieve not only the specified strength but also to meet the permeability requirement which are necessary to ensure durability of the structure.

3.4.8 Permeability Requirements

(a) Initial Surface Absorption Test (ISAT) shall be carried out on prototype samples of Different components of the bridge structures (e.g. pile cap, bridge deck, pier, pylon, abutment, parapet etc.) before the mix designs are approved.

The prototype samples shall be full size for precast elements and short sections of not less than 1.0m x 1.0m x full thickness for in-situ members. The samples shall be fully reinforced and cast in similar environment as the actual structure and cured in a regime

to be adopted for the structure. The ISAT tests shall be carried out in accordance with BS 1881:1970-1998 between 28-40 days after casting the samples and the maximum value shall not exceed the following limits at ten (10) minutes after starting the test.

- In-situ construction: Less than 0.10ml/m^2/s
- Precast concrete elements: less than 0.05 ml/m^2/s.

During construction, the ISAT test shall be used as in situ testing of structures and will form one of the basis for rejecting accepting concrete elements.

(b) Chloride permeability test

In addition to ISAT, the chloride permeability of the concrete shall be determined: using cores taken from the prototype samples cast for ISAT, in accordance with AASHTO T 277 'Rapid Determinations of the Chloride Permeability of Concrete'. The following limits shall not be exceeded.

- In-situ construction: 1000 coulombs.
- Precast concrete elements: 500 coulombs.

The frequency of the Chloride Permeability test shall be carried out as per Table 9 below or as instructed by the engineer.

TABLE 9 – FREQUENCY OF CHLORIDE PERMEALITY TEST

Element	Minimum numbers of tests
Precast Segmental Box Girders	One (1) test per 5 spans
Parapet	One (1) test per 200 panels
Piers	One (1) test per 5 piers
Pilecaps	One (1) test per 5 pilecaps
Precast Crosshead/ Hammerhead Beam	One (1) test per 5 crossheads/ hammerhead beams
Long Span Crossings and other Structure	One (1) test per 500 cu.m

During construction, the AASHTO T 277 test shall be used on cored samples and will form the basis for rejecting/accepting concrete elements.

(c) Initial Drying Shrinkage

The initial drying and shrinkage of all proposed concrete mixes prepared and tested in an approved laboratory and shall not exceed 0.06% unless the engineer relaxes this requirements to suit practical supply constraints as this test involves a testing period of about eight weeks.

(d) Depth of Penetration of Water Under Pressure

The depth of penetration of water under pressure in hardened concrete which has been water cured shall be carried out in accordance with BS EN 12390-8:2009.

(e) Percentage air content

An air content test is required for checking air-entrained concrete. The method of testing shall be carried out in accordance with BS EN 12350-7.

3.5 Concreting in Hot Weather

3.5.1 Mixing

In hot weather, suitable means shall be provided to shield the aggregate stockpiles from the direct rays of the sun or to cool the aggregates by spraying with water and to insulate the mixing water tank and pipelines to ensure that the temperature of the concrete when deposited shall not exceed 35°C.

3.5.2 Placing

In hot weather, suitable means shall be provided to avoid premature stiffening of concrete placed in contact with hot dry surfaces. Where necessary, the surfaces, including reinforcement, against which concrete is to be passed shall be shielded from the direct rays of the sun and shall be sprayed with water to prevent excessive absorption of water from the fresh concrete.

3.5.3 Ready-mixed Concrete

The temperature of ready-mixed concrete when deposited shall not exceed 35°C.

3.5.4 Heat of Hydration

The heat of hydration shall not cause a temperature differential between the interior of the concrete and any outside face greater than the value specified in Table 10 for the various types of aggregate used. The limiting temperature differential for various restraint factors R shall comply with the requirements of BS 8110. Records of the monitored temperature differential shall be submitted to the engineer for approval within one (1) week of each placing.

TABLE 10 – LIMITING TEMPERATURE DIFFERENTIAL

Aggregate Type	Limiting Temperature Differential When R = 0.36
Gravel	20.0°C
Granite	27.7°C
Limestone	39.0°C

3.5.5 Measures to Avoid Cracking in Large Pour

For large pours of thick concrete sections defines as any structural elements with a thickness exceeding 500mm, the contractor shall take extra precautionary measures according to proven practices in concrete technology to prevent any form of cracking due to temperature gradient and shrinkage effects. These shall be proposed by the contractor and may include one or more of the followings:

- Ground granulated blast- furnace slag (ggbs), pulverised fuel ash (pfa) or silica fume as a cement substitute to reduce heat of hydration and to increase durability and water tightness to concrete.
- Other admixtures to increase workability, improve durability and reduce heat of hydration if necessary. The admixture to be used in concrete shall not contain chlorides.
- Use of flaked ice or liquid nitrogen as an additive to the cement mix.
- A coolant system to contain the thermal difference and minimize thermal cracking of concrete.
- Controlled insulation of the concrete during curing.
- Delay in striking of formwork.

The temperature differential between the warmer interior portion and the cooler surface portion shall not exceed the values stated in Table 10. The maximum temperature within the element shall not exceed 70°C. The contractor shall proposed a method of placing, curing, temperature monitoring and any other measures for acceptance by the engineer. The contractor shall demonstrate that his proposal shall be adequate to prevent cracking arising from heat of hydration and drying shrinkage. The design mix submitted by contractor for acceptance shall take the above requirements into account.
The contractor shall carry out all necessary tests to demonstrate to the acceptance of the engineer, that his proposed mix design together with his proposals to limit temperature differentials and to prevent early thermal cracking are satisfactory. The contractor shall provide and install thermocouples with electronic data recording equipment and any other necessary equipment and instruments to measure and monitor the concrete temperatures.

The contractor shall propose the location and the number of points, for thermocouples for the acceptance of the engineer. Notwithstanding the above measures and precautions the contractor shall seal, repair, and rectify any cracks in any concrete elements with epoxy resins or other accepted materials at his own expense.

4.0 COMPLIANCE WITH SPECIFIED REQUIREMENTS

4.1 Prescribed Mix

A prescribed mix shall be judged on the basis of the specified mix proportions. The workability shall be chosen to suit the construction requirements.

Notwithstanding this, strength tests shall be carried out during the progress of work. The rate of sampling shall be as per Rate two (2) for ordinary structural concrete as in Table 11. For each sampling, three (3) test cubes shall be made. One (1) test cube from each sample-batch shall be tested for the 7-day compressive strength. If the cube strength falls below 75% of

the 28-day compressive strength, the contractor shall take necessary steps to review the process of the production of concrete for future use.

The remaining two (2) test cubes from the sample-batch shall be tested for the 28-days compressive strength. The appropriate strength requirement shall be considered to be satisfied if at least one of the following is complied with:-

(a) neither of the two (2) test cubes is below the specified compressive strength;

(b) the average strength of the two (2) test cubes is not less than the specified compressive strength and the difference between the two strengths is not more than 20% of the average strength.

In the event that the results of the test do not meet the specified requirements, the engineer shall determine the action to be taken in respect of the concrete member represented by the sample-batch test cubes. Such action may include demolition of the member. The contractor shall, if required by the engineer, take cored samples from the hardened concrete member and carry out the compressive strength test.

4.2 Designed Mix

4.2.1 Characteristic Strength

The characteristic strength of concrete is that 28-day cube strength, below which not more than 5% of the test results may be expected to fall. Compliance with the specified characteristic strength shall be judged by tests made on cubes at an age of twenty eight (28) days.

4.2.2 Sampling and Testing

All sampling and testing of constituent materials shall be carried out in accordance with the provisions of the appropriate available Malaysian Standards. In particular, sampling and testing of fresh and of hardened concrete shall be carried out in accordance with the provisions of MS 26.

The rate of sampling shall be as given in Table 11, but not less than one (1) sample shall be taken from each source of production on each day that concrete of any particular grade is used.

TABLE 11 - MINIMUM RATE OF SAMPLING

Volume of Concrete from which a sample shall be taken:-	
Rate 1 (Prestressed Concrete)	Every 10 cu.m or every group of 10 batches *
Rate 2 (Ordinary Structural Concrete)	Every 20 cu.m or every group of 20 batches *
Rate 3 (Mass Concrete)	Every 50 cu.m or every group of 50 batches *

* The sample shall be taken from one (1) single batch randomly selected from the group of batches.

4.2.3 Testing Plan

Five (5) test cubes shall be made from a single sample taken from a randomly selected batch of concrete. The samples shall be taken at the point of discharge from the mixer or, in the case of ready-mixed concrete, at the point of discharge from the delivery vehicle.

Two (2) test cubes from each sample shall be tested for the 7-days compressive strength. If the cube strength falls below the 7-days strength as determined from the trial mixes, then the contractor shall take the necessary steps to review the process of the production of concrete and make certain adjustments where applicable.

The remaining three (3) test cubes from the same sample shall be tested for the 28-days compressive strength. The average strength of the two (2) cubes shall constitute the 28-days compressive strength of the sample.

For compliance purposes: -

(i) The average 28-days strength determined from any group of four (4) consecutive samples shall exceed the specified characteristic strength by at least 0.5 times the current margin.

The current margin shall be taken as 10 N/mm² for concrete of grade 15 or 15 N/mm² for concrete of grade 20 or above unless, in accordance with Sub-section 3.3.1 or 3.3.5 (b), a smaller margin has been established.

In this respect, consecutive samples are samples taken at intervals not exceeding fourteen (14) days. In all cases, at least four (4) samples shall be taken of concrete on the first day of concreting for each grade of concrete to be used in the work, irrespective of the volume of concrete produced or the sampling rate.

(ii) Each individual sample test result shall be at least 85% of the specified characteristic strength.

If any one (1) sample test result fails to meet the second requirement (ii), then that result may be considered to represent only the particular batch of concrete from which the sample test cubes were taken.

If the average strength of any group of four (4) consecutive sample test results fails to meet the first requirement (i), or more than one sample test result in a group fails to meet the second requirement (ii), then all the concrete in all the batches represented by all such sample test results shall be deemed not to comply with the strength requirements.

For the purpose of this Sub-section batches of concrete represented by groups of four (4) consecutive sample test results shall include the batches from which samples were taken to obtain the first and the last sample results in the group of four, together with all the intervening batches.

4.3 Additional Cubes

Additional cubes may be required for various purposes. These shall be made and tested in accordance with MS 26 but the methods of sampling and the conditions under which the cubes are stored shall be varied according to the purpose for which they are required.

For determining the cube strength of prestressed concrete before transfer or of concrete in a member before striking formwork, sampling shall be at the point of placing and the cubes shall be stored as far as possible under the same conditions as the concrete in the members.

The extra cubes shall be identified at the time of making and shall not be used for the normal quality control or compliance procedures.

4.4 Testing of Hardened Concrete Cut from the Works

Cylindrical core specimens of 100mm or 150mm diameter shall be cut from the hardened concrete in the Work for the purpose of examination and testing. The cutout specimens shall be dealt with in accordance with BS 1881. Prior to the preparation for testing, the specimens shall be made available for examination by the engineer.

If the equivalent cube strength of the specimen is less than the appropriate specified minimum crushing strength, or, if in the opinion of engineer, the concrete fails to meet the specified requirements in other respects, the concrete in that part of the work of which it is a sample will be considered not to have complied with the specified requirements.

4.5 Accredited Testing Laboratory

The cube test shall be carried out by accredited and independent test laboratory approved by engineer.

5.0 PRODUCTION OF CONCRETE

5.1 Supervision

The contractor shall ensure the required standard of control over materials and workmanship. The engineer shall be afforded all reasonable opportunity and facility to inspect the materials and the production of concrete, to take any samples and to make any test and all costs connected with the testing shall be borne by the contractor.

5.2 Batching and Mixing

The quantities of cement, fine aggregate and various sizes of coarse aggregate shall be measured by weight. A separate weighing machine shall be provided for weighing the cement. Alternatively the cement may be measured by using a whole number of bags in each batch. The quantity of water shall be measured by volume or by weight. Any solid admixtures to be added shall be measured by weight but liquid or paste admixtures may be measured by volume or weight.

The batch weight of aggregate shall be adjusted to allow for the moisture content of the aggregate being used. The accuracy of the measuring equipment shall be within:-

(a) ± 3% of the quantity of cement per batch;

(b) ± 3% of the quantity of water per batch;

(c) ± 3% of the quantity of total aggregate per batch;

(d) ± 5% of the quantity of admixture per batch.

The mixing time shall be not less than two (2) minutes or more than five (5) minutes after all the ingredients have been placed in the mixer.

Mixers that have been out of use for more than thirty (30) minutes shall be thoroughly cleaned before any fresh concrete is mixed. The first batch of concrete through the mixer shall then contain only two-thirds of the normal quantity of coarse aggregate. Mixing type plant shall be thoroughly cleaned before changing from one type of cement to another.

The water content of each batch of concrete may be adjusted so as to produce a concrete of the required workability.

5.3 Transporting

Concrete shall be transported from the mixer to the formwork as rapidly as practicable by methods, which will prevent segregation or loss of the ingredients and maintain the required workability. It shall be deposited as near as practicable in its final position to avoid rehandling. The concrete shall be conveyed by chutes or concrete pumps only with permission from the engineer.

5.4 Placing

For all concrete whether mixed on or off the site of the Works, each batch shall be placed and compacted within two (2) hours of adding the cement to the dry aggregates and within forty five (45) minutes of adding water to the cement and aggregates. Concrete shall not be placed in any part of the structure until the engineer's approval has been obtained. If concreting is not started within twenty four (24) hours of approval given, approval shall again be obtained from the engineer.

All formwork and reinforcement contained in it shall be clean and free from standing water immediately before the placing of the concrete. Concreting shall be carried out continuously between and up to predetermined construction joints in one sequence of operation. In the event of unavoidable stoppage in positions not predetermined, the concreting shall be terminated on a horizontal plane and against vertical surfaces by the use of stopping-off boards.

Fresh concrete shall not be placed against in situ concrete, which has been in position for more than forty five (45) minutes unless a construction joint is formed in accordance with

Sub-section 6.1. When in situ concrete has been in place for four (4) hours, no further concrete shall be placed against it for a further twenty (20) hours.

Concrete shall be deposited in horizontal layers to a compacted depth not exceeding 450 mm where internal vibrators are used, or 300 mm in all other cases. The surface of the concrete shall be maintained reasonably level during placing.

Concrete shall not be dropped into place from a height exceeding 1500 mm. When trunking or chutes are used, they shall be kept clean and used in such a manner as to avoid segregation.

For sections involving horizontal placing of the concrete (e.g. deck slabs), the concrete shall be placed in such quantities as will allow the member to be cast to its full depth along the full width between the side forms and then gradually brought towards the finishing points along its entire front parallel to the end forms, the tamping and compacting equipment following as closely behind as practicable.

The contractor shall maintain an experienced steel fixer at the Site of reinforced concrete works during the placing of concrete to reposition any reinforcement, which may be displaced during the work.

Should any unforeseen occurrence result in a stoppage of concreting for such time as might allow the concrete already placed to begin to set before the next batches can be compacted into place, the contractor shall immediately insert an end form normal to the work at the stopping point to form a construction joint.

No concrete shall be placed in flowing water. Underwater concrete if deemed unavoidable by the engineer shall be placed in position by tremies or pipelines from the mixer. Concrete to be placed under water shall be an approved mix with the amount of cement increased by 20%. During and after concreting under water, pumping or dewatering operations in the immediate vicinity shall be suspended until the engineer permits them to continue. Where the concrete is placed by a tremie, the following requirements shall be applicable: -

(i) When concreting of bored piles is being carried out under water, temporary casing shall be installed to the full depth of the borehole so that fragments of ground cannot drop from the sides of the hole into the concrete as it is placed;

(ii) The hopper and tremie pipe shall be a closed system. The bottom of the tremie shall be kept as far as practicable beneath the surface of the placed concrete;

(iii) The tremie pipe shall be large enough with due regard to the size of aggregate. For 20 mm aggregate the tremie pipe shall be of diameter not less than 150 mm and for larger aggregate, a larger diameter tremie pipe shall be required;

(iv) The first charge of concrete shall be placed with a sliding plug pushed down the tube ahead of it to prevent mixing of concrete and water;

(v) The tremie pipe shall always penetrate well into the concrete with an adequate margin of safety against accidental withdrawal if the pipe is surged to discharge the concrete;

(vi) The concrete shall be deposited wholly by tremie and the method of deposition shall not be changed part way up to prevent the laitance from being entrapped within the structure;

(vii) All tremie pipes shall be scrupulously cleaned after use.

5.5 Temperature Requirements

During hot weather, additional precautions shall be taken to prevent premature setting and loss of water during placing of concrete in the formwork. These precautions shall include:-

(i) No concrete having an internal temperature exceeding 33°C shall be deposited;

(ii) Concrete shall not be placed in formwork or around reinforcement whose temperature exceeds 35°C;

(iii) Newly placed concrete shall be protected from direct sunlight and from loss of moisture by covering, shading or other means;

(iv) No concrete shall be placed when the air temperature at the point of deposition exceeds 35°C.

5.6 Compaction

Concrete shall be thoroughly compacted by vibration and thoroughly worked around the reinforcement, tendons, or duct formers, around embedded fixtures and into corners of the formwork to form a dense homogeneous mass free from voids and which will have the required surface finish when the formwork is removed. Vibration shall be applied continuously during the placing of each batch of concrete until the expulsion of air has practically ceased and in a manner, which does not promote segregation of the ingredients.

Concrete shall be compacted by internal vibrators and concrete in slabs with no formwork on its upper surface shall be compacted either by vibrators of the pan type or by a vibrating screed.

The internal vibrators shall be inserted and withdrawn slowly and at a uniform pace of approximately 100 mm per second. Compaction shall be deemed to be completed when cement mortar appears in an annulus around the vibrator. Over vibration leading to segregation of the mix must be avoided. The internal vibrators shall be inserted at points judged by the area of mortar showing after compaction, with a certain allowance made for overlapping, and they shall not be allowed to come into contact with the formwork or the reinforcement and shall be inserted at a distance of not less than 75 mm from the former.

The pan vibrator shall be placed on the surface of the concrete, which shall have previously been tamped and levelled leaving an allowance in height for compaction until the cement mortar appears under the pan. The vibrator shall then be lifted and placed on the adjoining surface and this operation shall be repeated until the whole surface has been compacted. Alternatively a vibrating screed spanning the full width of the surface may also be used.

Whenever vibration has to be applied externally, the design of formwork and disposition of vibration shall receive special consideration to ensure efficient compaction and to avoid surface blemishes. The mix shall be such that there will be no excess water on the top surface on completion of compaction.

External vibrators shall be firmly secured to the formwork which must be sufficiently rigid to transmit the vibration and strong enough not to be damaged by it.

Internal vibrators shall be capable of operating at not less than 10,000 cycles per minute and external vibrators at not less than 3,000 cycles per minute. Sufficient vibrators in serviceable condition shall be on Site so that spare equipment is always available in the event of breakdown.

Concrete shall not be subjected to any disturbance within twenty-four (24) hours after compaction. No standing or flowing water shall be allowed to come into contact with exposed concrete surfaces during the first few hours after placing and compaction of the concrete.

5.7 Ready-Mixed Concrete

Ready-mixed concrete shall comply with the requirements of MS 523. The concrete shall be carried in purpose-made agitators operating continuously or truck mixers. The concrete shall be compacted and in its final position within two (2) hours of the introduction of cement to aggregate and within forty five (45) minutes after the addition of water to the cement-aggregate mix. The time of such introduction shall be recorded on the Delivery Note together with the weight of the constituents of each mix.

When concrete is transported by truck from the batching plant, water shall be added under supervision either at the Site or at the central batching plant but under no circumstances shall water be added in transit.

Ready-mixed concrete delivered to the Site shall be accompanied by manufacturer's certificate stating the details of mix proportions by weight, grade of concrete, type and size of aggregate, date and time of production, type and dosage of chemical admixtures and other relevant production details in suitable format. In addition the contractor shall supply to engineer the manufacturer’s test certificates for testing of materials, indicating the sources of supplies and other relevant details.

5.8 Curing and Protection

All work shall be protected from damage by shock or overloading or falling earth or flowing water, etc.

5.8.1 Normal Curing

Exposed surfaces, immediately after compaction, shall be protected from the sun and rain. All concrete, after it has set, shall be kept continuously damp until thoroughly cured. Provision shall be made for adequate water distribution to all parts of the works, so that if required, this treatment can be continued efficiently throughout the whole period of construction. In order to keep the concrete continuously damp, all exposed surfaces shall be covered with damp

gunny sacks or shall have water impounded on them for the full period of curing, which shall be not less than seven (7) days.

Beyond seven (7) days after pouring and up to fourteen (14) days, all concrete surfaces shall be protected from the direct rays of the sun and exposure to severe dry winds. The surface shall be kept damp by occasional hosing. The frequency of hosing shall depend on prevailing weather conditions. At no time during this period shall any surface be allowed to be totally free of surface moisture.

5.8.2 Accelerated Curing

Elevated temperature curing may be used only with ordinary Portland cement. After the completion of the placing of the concrete, four (4) hours shall elapse before its temperature is raised.

The rise in temperature within any period of thirty (30) minutes shall not exceed 10°C and the maximum temperature attained shall not exceed 70°C. The rate of subsequent cooling shall not exceed the rate of heating. The use of accelerated curing methods for concrete containing other types of cement or any admixture shall be subject to the approval of the engineer.

6.0 CONSTRUCTION WITH CONCRETE

6.1 Construction Joints

The position and detail of any construction joints not described in the Contract shall be subject to the approval of the engineer and shall be so arranged as to minimize the possibility of the occurrence of shrinkage cracks.

If for any unavoidable reason the contractor has to interrupt a planned pour for more than forty-five (45) minutes, additional construction joints shall be positioned and constructed.

The number of construction joints shall be kept to a minimum consistent with reasonable precautions against shrinkage. Concreting shall be carried out continuously up to construction joints. The joints shall be at right angles to the general direction of the member and shall take due account of shear and other stresses.

Concrete shall not be allowed to run to a feather edge and vertical joints shall be formed against a stop board. The top surface of a layer of concrete shall be level and flat unless design considerations make this undesirable. Joint lines shall be so arranged that they coincide with features of the finished work, wherever possible.

At horizontal construction joints, gauge strips about 25 mm x 25 mm in section shall be placed inside the forms along all exposed surfaces to ensure a straight joint on those surfaces.

If a kicker (i.e. starter stub) is used it shall be at least 70 mm high and carefully constructed. It is preferable for the kicker to be incorporated with the previous concrete. Where possible, the formwork shall be designed to facilitate the preparation of the joint surface, as the optimum time for treatment is usually two (2) to four (4) hours after placing.

Where vertical construction joints are necessary in mass concrete structures, reinforcing bars shall be placed across the joints so as to make the structure monolithic.

Prior to recommencement of concreting on a joint, the surface of the concrete against which new concrete will be cast shall be free from laitance and shall be roughened to the extent that the largest aggregate is exposed but not disturbed. Care shall be taken to avoid damaging the lines of the joint. Care shall also be taken that the joint surface is clean and damp but not wet. Immediately before the fresh concrete is placed against the joint, fresh cement mortar shall be applied to the exposed surface.

For an in situ structural connection, preparation shall be carried out, when the concrete has set but not hardened, by spraying with a fine spray of air and water or brushing with a stiff brush sufficiently to remove the outer mortar skin and expose the larger aggregates without disturbing them. Where this treatment is impracticable, sand blasting or a needle gun shall be used to remove the surface skin and laitance. Hardened surfaces shall not be hacked.

6.2 Fixing Blocks, Brackets, Built-In-Bolts, Holes, Chases, etc.

All fixing blocks, brackets, built-in bolts, holes, chases, etc. shall be accurately set out and formed and carefully sealed prior to the concrete being placed. No cutting away of concrete for any of these items shall be done without the permission of the engineer.

Bolts and other inserts to be cast into the concrete shall be securely fixed to the formwork in such a way that they are not displaced during the concreting operations, and that there is no loss of materials from the wet concrete through holes in the formwork.

Unless shown otherwise on the Drawings, reinforcement shall be locally moved so that the minimum specified cover is maintained at the locations of inserts, holes, chases, etc.

Temporary plugs shall be removed and the threads of built-in bolts shall be proved to be free and shall be greased before handing over any part of the Works.

6.3 Precast Concrete Construction

6.3.1 Manufacture off the Site

After the method of manufacture has been approved by the engineer, no changes shall be made without the consent of the engineer.

The contractor shall inform the engineer in advance of the date of commencement of manufacture and casting of each type of item.

When the engineer requires tests to be carried out, no items to which the tests relate shall be dispatched to the Site until the tests have been satisfactorily completed and the results approved by the engineer.

All items shall be indelibly marked to show the item mark, the production line on which they were manufactured, the date on which the concrete was cast and, if they are of symmetrical section, the face that will be uppermost when the member is in its correct position in the works.

6.3.2 Storage

When items are stored, they shall be firmly supported only at the support points as specified. The accumulation of trapped water and deleterious matter in the units shall be prevented. Care shall be taken to avoid rust staining and efflorescence.

Items shall be stacked in such a manner that their removal in correct order of age is facilitated.

6.3.3 Handling and Transport

Items shall be lifted only at points as described in the Specification, and shall be handled and placed without impact.

The method of lifting, the type of equipment and transport to be used, and the minimum age of the items to be handled shall be subject to the approval of the engineer.

6.3.4 Assembly and Erection

The method of assembly and erection described in the Specification shall be strictly adhered to on the Site.

Immediately a unit is in position, and before the lifting equipment is removed, temporary supports or connections between items, as necessary, shall be provided. The final structural connections shall be completed as soon as is practicable.

6.3.5 Forming Structural Connections

No structural connections shall be made until approval has been given by the engineer.

The composition and water/cement ratio of the in situ concrete or mortar used in any connection and the packing of joints shall be in accordance with the assembly instructions.

Levelling devices shall only be released or removed with the approval of the engineer.

6.3.6 Falsework

Falsework and centring shall be designed to provide the necessary rigidity to support all loads placed upon it without settlement or deformation in excess of the permissible tolerance for the structure. Falsework columns shall be supported on hardwood, concrete pads or metal bases if it cannot be founded on rock or thick deposit of other compact material in their natural beds. Falsework shall not be supported on any part of the structure, except the footings, without the written permission of the engineer. The number and spacing of falsework columns, the adequacy of sills, caps and stringers and the amount of bracing in the falsework framing shall be subject to approval of the engineer.

Timber may, with the approval of the engineer, be used in falsework as joists, stringers and floors beams. All timber shall be of sound wood, in good condition and free from defects that might impair its strength. If the vertical members are of insufficient length to cap at the desired elevation for the horizontal members, they shall preferably be capped and frames constructed to the proper elevation. Ends of the vertical members shall be cut square for full bearing to preclude the use of wedges. If vertical splices are necessary, the abutting members shall be of the same approximate size, the ends shall be cut square for full bearing, and the splice made in a manner approved by the engineer.

The contractor shall compute falsework settlement and deflection for bridges to that when the final settlement is complete, the structure will conform to the required camber, section and grade as shown on the Drawings.

The contractor shall provide means for accurately measuring settlement in falsework during placement of concrete, and shall provide a competent observer to observe and correct the settlement.

Screw jacks, if used, shall be designed for use with a slenderness ratio not exceeding 60. The slenderness ratio shall be taken as the ratio of the clear distance between effective bracing in both horizontal directions to the diameter of the screw jack measured at the root of the thread. The manufacturer's certificate showing the ultimate load capacity of the screw jack shall be submitted with the design calculations for the falsework. If directed by the engineer, the contractor shall furnish a test certificate carried out at an approved independent laboratory.

Props and towers supporting forms or partially completed structure shall be interconnected in plan orthogonally at levels to be determined in the design. They shall also be interconnected by diagonal bracing in orthogonal vertical planes.

6.3.7 Submittal of Calculations

The contractor shall submit, together with the calculations and shop drawings of falsework and temporary construction, the following calculations for the approval of the engineer.

i) Stresses during construction

ii) Jacking forces required during temporary post-tensioning

iii) Computations of deflections, camber and geometry control.

Prototype Sample

The contractor is required to satisfy the engineer, by carrying out prototype sample(s) on site that the specified quality of finish can be consistently obtained using the proposed forms, liners and concreting procedures. The contractor shall, at his own expense, carry out as many trial samples as required by the engineer until a sample to the approval of the engineer is produced. No Pre-casting of segment for the permanent works will be permitted until a satisfactory prototype sample is produced. The accepted prototype shall be displayed on site for the duration of the Works and shall be taken as the benchmark by which the finish of all deck segments shall be judged for acceptance or rejection.

6.3.8 Form for box girder segments

Formwork for box girder segments must satisfy the following tolerances:

(a) Web thickness, +10mm or –5mm

(b) Thickness of bottom slab +5mm, but 0 reduction in depth.

(c) Thickness of top slab +5mm, but 0 reduction in depth.

(d) Overall width of unit, ±5mm

(e) Overall depth of unit, ±5mm

(f) Length of match cast unit, ±3mm

(g) But not cumulative and a maximum of 50mm per span.

(h) Diaphragm dimensions, +10mm or –5mm

(i) Grade at top and bottom flanges, +3mm or –3mm.

6.4 Spacers and Chairs

Spacers and chairs shall be placed at a maximum spacing of 1,000 mm centers to maintain the specified nominal cover to the steel reinforcement.

Spacer shall be durable and of such materials and design not leading to corrosion of the reinforcement and not causing appearance spalling of the concrete cover.

The mix used for spacer blocks made from cement, sand and small aggregate shall be comparable in strength, durability, porosity and appearance to the surrounding concrete.

6.4.1 Solid Slabs

6.4.1.1 Bottom Face

All bar reinforcement nearest to the bottom face shall be supported by spacers at 50d centers with a maximum of 1,000 mm centers and staggered (see Diagram 1).

Welded fabric shall be supported by spacers not exceeding 500mm centers in two (2) directions at right angles (see Diagram 1).

6.4.1.2 Top Face

Top reinforcement (individual bars or welded fabric) shall be supported off the bottom reinforcement by continuous chairs at 50d centers (see Diagram 2).

Where there is no bottom reinforcement, the top reinforcement shall be supported from the formwork by the use of individual chairs with protective tips or by continuous chairs at 50d centers resting on line spacers placed at a maximum of 500mm centers (see Diagram 3).

In all cases, continuous chairs supporting individual bars or welded fabric shall provide a line of support to groups of adjacent bars at centers not exceeding fifty (50) times the size of the bars they are supporting.

6.4.1.3 Edges

Vertical reinforcement nearest to the edge surface at right angles to the top and bottom surfaces of the slab (including bent bars) shall have spacers on alternative vertical bars (see Diagram 4).

Horizontal reinforcement parallel to the edge of the slab shall have spacers at 50d centers but not exceeding 1,000mm centers on each bar (see Diagram 4).

6.4.2 Waffle, Trough and Ribbed Slabs

Where main bars are supported by links in the ribs of waffle and ribbed slabs, spacers shall be fixed to the links at centers not exceeding 1,000mm along the rib. Three (3) spacers are required on each link, one (1) at mid-height on each of the two (2) vertical legs, and one (1) on the horizontal part of the link in the center. Where the main bars are not supported by links, rib spacers shall be fixed to the main bars at centers fifty (50) times the size of main bars or a maximum of 1,000mm centers (see Diagram 5). Spacers to reinforcement in topping and in solid areas shall be in accordance with the requirements for solid slabs or cantilever slabs.

6.4.3 Cantilever Slabs

At the point where the cantilever joins the main structure, continuous chairs shall be provided to support the top reinforcement, with the centers of successive chairs along the bars at 50d but not exceeding 1,000mm. In the case of solid slab cantilevers, the top reinforcement shall be supported by continuous chairs resting on bottom reinforcement. Where there is no bottom reinforcement, top reinforcement shall be supported from the formwork by the use of chairs with protective tips or by continuous chairs resting on line spacers.

6.4.4 Beams

Spacer shall be fixed to links adjacent to the vertical side of formwork, at both ends of the beam and at centers not exceeding 1,000mm along the beam (see Diagram 6).

6.4.4.1 Bottom Face

For beams less than 250mm wide, one (1) spacer shall be provided in the middle (see Diagram 6).

For beams greater than 250mm but less than 500mm wide, two (2) spacers, one (1) at each of the corner reinforcement shall be provided (see Diagram 6).

For beams greater than 500mm wide, three (3) or more spacers at 50d centers shall be provided (see Diagram 6).

6.4.4.2 Side Face

For beams less than 100d depth, one (1) spacer shall be provided at midheight (see Diagram 6). For beams greater than 100d depth, spacers shall be provided at centers not exceeding 50d (see Diagram 6).

6.4.4.3 End Face

Every end termination of a bar at exposed concrete faces shall have a suitable spacer (see Diagram 6).

6.4.5 Columns

All spacers shall be fixed to links at the top, middle and bottom of each lift of concrete at centers not exceeding 100d.

For small, square or rectangular columns with sides not exceeding 50d, one (1) spacer shall be fixed in the middle of each of the shorter sides and two (2) spacers on each of the other two sides (see Diagram 7).

For wide columns with sides exceeding 50d, three (3) or more spacers at centers not exceeding 50d shall be provided (see Diagram 7).

For circular columns, a minimum of four (4) equally spaced spacers per link (one pitch for a helix) at 50d centers shall be provided (see Diagram 7).

For multi-faceted columns, at least one (1) spacer per facet shall be provided. Facets exceeding 50d shall have two (2) or more spacers at 50d centers (see Diagram 7).
Spacers for spiral links shall be as those for circular columns.

6.4.6 Walls

For bars or fabric, face cover shall be maintained by spacers on the reinforcement nearest to the face, at centers of 50d but not exceeding 500mm in two (2) directions at right angle to each other and staggered (see Diagram 8).

Bars or fabrics in opposing faces shall be separated by rows of continuous chairs, preferably vertical, at not more than 1,000mm centers and located at the same positions as the outer spacers (see Diagram 8).

6.4.7 Foundations

The requirements for reinforcement for reinforced strip footings, individual bases, ground beams, ground slabs and pile caps are the same as those for solid slabs and beams.

6.5 Accuracy in Construction

The dimensional deviations of all constructed structural elements shall not exceed the permissible tolerances as specified in BS 5606: 1990 (1998).

6.6 Protection

At all stages of construction, precast concrete units and other concrete associated therewith shall be properly protected to prevent damage to permanently exposed surfaces, especially arises and decorative features.

7.0 STEEL REINFORCEMENT

7.1 Description

The work shall consist of furnishing and placing reinforcing steel in accordance with this Specification and in conformity with the drawings.

7.2 Materials

Hot rolled mild steel and high yield bars shall comply with the requirements of MS 146, as denoted on the Drawings. Cold worked steel bars shall comply with the requirements of BS 4461. Hard drawn mild steel wire shall comply with the requirements of MS 144.

Steel fabric reinforcement shall comply with the requirements of MS 145 and shall be delivered to the Site in flat sheets. Bar-mats shall conform to the requirements of MS 146 and shall consist of bars of the sizes and spacings as shown on the Drawings.

Dowel bars shall be plain round bars conforming to the requirements of MS 146. They shall be free from burring or other deformations restricting slippage in the concrete. Dowel bar sleeves used for debonding shall be of approved synthetic material. The closed end of the sleeve shall be filled with 25 mm thick compressible foam filler and the sleeve shall fit tightly over the length of bar to be debonded.

The contractor shall furnish manufacturer's certificates for reinforcement supplied to him, and these shall be submitted for acceptance by the engineer before any material is brought onto the Site. The characteristic strengths of steel reinforcement are given in Table 12.

TABLE 12 - CHARACTERISTIC STRENGTH OF STEEL REINFORCEMENT

Designation	Nominal Sizes (mm)	Characteristic Strength, fy (N/sq.mm)
Hot rolled grade 250 (MS 146)	All sizes	250
Hot rolled grade 460 (MS 146)	All sizes	460
Cold worked (BS 4461)	All sizes	460
Hard drawn steel wire (MS 144)	Up to and including 12mm	485
Steel Fabric (MS 145)	Up to and Including 12mm	485

Binding wire shall be 1.6 mm diameter soft annealed steel wire complying with the requirements of BS 1052.

The contractor shall furnish the engineer with samples of reinforcement brought onto the Site, notwithstanding any previous acceptance of the manufacturer's test certificates. The reinforcement represented by the sample shall be rejected by the engineer if the sample fails in testing to meet the Specification.

Steel reinforcement shall be stored in clean and dry conditions. When placed in the Works it shall be clean and free from loose rust, mill scale, oil, grease, paint, dirt or anything, which may reduce its bond with concrete.

The steel shall be brushed or otherwise cleaned before use, at the contractor's expense.

7.3 Construction Methods

7.3.1 Cutting and Bending of Reinforcement

Bars shall be cut to their correct lengths and bent to the exact shapes required before being fixed in the work.

Bars shall be cut and bent cold by the application of slow, steady pressure or in an approved bar-bending machine. Bending at temperatures in excess of 100° C shall not be carried out. Except where otherwise indicated on the Drawings, bars shall be bent and measured in accordance with BS 4466.

Cold worked and hot rolled bars shall not be straightened or bent again once having been bent. Where it is necessary to bend mild steel reinforcement already cast in the concrete, the internal radius of bend shall be not less than twice the diameter of the bar.

Special care shall be taken that the overall length of bars with multiple bends is accurate and that after bending and fixing in position the bars remain in place without wrap or twist.

7.3.2 Fixing of Reinforcement

The number, size, length, form and position of all reinforcing bars, links, stirrups, spacer bars and other parts of the steel reinforcement, shall be in accordance with the Drawings.

Reinforcement shall be secured against displacement. Unless specified otherwise, the actual concrete cover shall be not less than the required nominal cover minus 5 mm. In a member where the nominal cover is dimensioned to the links, spacers between the links and formwork shall be of the same dimension as the nominal cover. The nominal cover to reinforcement under different conditions of exposure and for specified periods of fire resistance shall be as per BS 5400. Longitudinal location of bends and ends of reinforcing bars shall be ±25 mm except that the specified cover at ends bars of members shall not be reduced by more than 3 mm.

All intersecting bars shall be tied together with binding wire and the ends of the wire shall be turned into the main body of the concrete.

The contractor shall take particular care that the reinforcement is laid out correctly in every respect and temporarily suspended by annealed wire or supported on concrete blocks or other approved spacers in the forms to prevent displacement before or during the placing and compacting of concrete.

Stirrups and distance pieces shall be tied securely to the bars they embrace or support and all reinforcement shall be kept away from the face of the concrete at the distances shown on the Drawings.

No concrete shall be placed until the reinforcement has been inspected and approved by the engineer. Reinforcement temporarily left projecting from the concrete at construction or other joints shall not be bent out of position during the periods in which concreting is suspended except with the approval of the engineer.

7.3.3 Splicing

Laps and joints including lapping bars, sleeving, threading and other mechanical connections shall be made strictly in accordance with the method specified and at the positions shown on the Drawings.

7.3.4 Supporting and Spacer Blocks

Supporting and spacer blocks required for ensuring that the reinforcement is correctly positioned shall be as small as possible consistent with their purpose and designed so that they will not overturn when the concrete is placed. They shall be made of concrete with 10 mm maximum aggregate size and they shall be of at least the same strength and material source as the adjacent concrete. Wire cast in the block for the purpose of tying it to the reinforcement shall be as described in Sub-section 7.2.

7.3.5 Welding of Reinforcement

Reinforcement in structure shall not be welded except where detailed on the Drawings or required by the Specification. If the reinforcement needs to be welded, the reinforcement shall comply with the requirements of BS 4360:1986.

Welding shall be carried out in accordance with BS 5135 and BS 638. Butt welds shall be of the double V type and two butt weld bond tests shall be carried out on a specimen prepared to represent each form of butt welded joint used in welding the reinforcement and for each position of welding. The method of making butt weld tests shall be that laid down in BS 709. The specimen shall pass the test before approval is accorded to use the joint, which the specimen represents.

Welded joints shall not be made at bends in reinforcement. Joints in parallel bars of the principal tensile reinforcement shall be staggered in the longitudinal direction at a distance not less than the end anchorage length for the bar. Welded joints shall be performed by a competent welder.

The engineer shall be informed in advance of when welding is to be carried out so that he may supervise and inspect the work. Welding shall not be performed in the field during rain or other adverse conditions.

7.3.6 Rust Inhibitor for Exposed Reinforcement

All reinforcement exposed from structures for lapping purpose for the next contractor to proceed with the works are to be sprayed on coated with a water-soluble rust inhibition and wrapped in hessian backed paper.

8.0 FORMWORK AND SURFACE FINISH FOR STRUCTURE

8.1 Design and Construction

8.1.1 Description

Formwork shall include all temporary or permanent forms required for forming the concrete, together with all temporary construction required for their support.

The design and construction of formwork shall be carried out by competent persons. The contractor shall submit strength and deflection calculations and drawings of the proposed formwork to the engineer for prior approval. Notwithstanding any approval by the engineer with respect to the design submitted by the contractor, the responsibility or the adequacy and safety of the design shall remain with the contractor.

The formwork shall be sufficiently rigid and tight to prevent loss of grout or mortar from the concrete at all stages of construction and shall be appropriate for the methods of placing and compacting.

Formwork (including supports) shall be sufficiently rigid to maintain the forms in their correct position, shape, profile and dimensions. The supports shall be designed to withstand the worst combination of forces due to self-weight, formwork weight, formwork forces, reinforcement weight, wet concrete weight, construction and wind loads, together with all incidental dynamic effects caused by placing, vibrating and compacting the concrete.

Where internal metal ties are permitted they or their removable parts shall be extracted without damage to the concrete and the remaining holes filled with mortar of the same strength as the cast concrete. No permanently embedded metal parts shall have less than the specified cover to the finished concrete surface. Except for ties used for anchoring void formers all ties shall be at least 1.2 metres apart and through bolts will not be permitted on exposed faces. All holes left by ties shall be made good within one (1) day of the removal of the formwork using a mortar of the same strength as the cast concrete.

The formwork shall be so arranged as to be readily dismantled and removed from the cast concrete without shock, disturbance or damage. Where necessary, the formwork shall be so arranged that the soffit form, properly supported, can be retained in position, for such period as may be required by the condition of the maturing concrete or the Specification. If a component is to be prestressed whilst still resting on the soffit form, provision shall be made to allow for elastic deformation and any variation in weight distribution. As far as practicable, formwork joints shall coincide with construction joints.

8.1.2 Voids in Concrete

Voids, where shown on the Drawings, shall be formed with non-recoverable void formers of expanded polystyrene, or by other methods approved by the engineer. They shall not deviate by more than 12 mm from the positions shown on the Drawings, nor shall the cross-section deviate from the specified shape by more than 12 mm.

Void formers shall be secured and adequately anchored to prevent movement or flotation outside the limits specified above, during the concreting operation. Anchor ties secured to the soffit form will be permitted provided they comply with the requirements of Sub-section 8.1.

Void formers of expanded polystyrene need not be vented. Hollow void formers shall be vented by the provision of 50 mm diameter holes between each void and the soffit.

As soon as possible and at least three (3) months prior to the casting of the first deck slab with voids, the contractor shall construct a model of a size and form to be agreed with the engineer using the proposed formers, methods of fixing, and simulating reinforcement and prestressing cable ducts, to demonstrate that the proposed methods of fixing the formers and placing concrete around them and the reinforcement will produce voids within the tolerances, surrounded with properly compacted concrete of the required strength.

The attention of the contractor is drawn to the flammable nature of expanded polystyrene and he shall take all necessary precautions to minimize the risk of fire.

Concreting of voided slabs in structures shall not commence until the model test has been completed and approved by the engineer.

8.1.3 Form Lining

The type and treatment of any lining (plywood, metal, plastic, etc.) of the forms shall be appropriate to the concrete finish required.

8.1.4 Projecting reinforcement, Fixing Devices

Where holes are needed in forms to accommodate projecting reinforcement or fixing devices, care shall be taken to prevent loss of grout when concreting or damage when removing forms.

8.2 Finishes

8.2.1 Formed Surfaces

Formed concrete surfaces shall have one of the following classes of finish. Unless otherwise specified, all exposed concrete surfaces shall be of Class F2 finish and all unexposed surfaces shall be of Class F1 finish. Class F3 finish shall be used only where shown on the Drawings.

8.2.1.1 Class F1

This finish shall be obtained by the use of properly designed formwork of closely jointed sawn timber or other approved material. Small blemishes caused by entrapped air or water may be expected but the surface shall be free from voids and honeycombing.

8.2.1.2 Class F2

This finish shall be obtained by the use of properly designed formwork of closely jointed wrought boards, approved plywood or other approved material. Only very minor surface blemishes shall occur, with no staining or discolouration.

8.2.1.3 Class F3

This finish shall be obtained by the use of properly designed steel forms or plastic coated plywood or wrought boards or other approved material. The surface shall be improved by carefully removing all fins and other projections, thoroughly washing down and then filling the most noticeable surface blemishes with a cement and fine aggregate paste to match the colour of the original concrete. Form release agent shall be carefully chosen to ensure that the surface shall not be stained or discolored. After the concrete has been properly cured, the surface shall be rubbed down where necessary, to produce a smooth and even surface.

8.2.2 Unformed Surfaces

8.2.2.1 Class U1

The concrete shall be uniformly levelled and screeded to produce a plain, ridged or broom roughened surface. No further work shall be applied to the surface unless it is used as the first stage for a Class U2 or Class U3 finish.

8.2.2.2 Class U2

After the concrete has hardened sufficiently, the concrete Class U1 surface shall be floated by hand or machine to produce a uniform surface free from screed marks.

8.2.2.3 Class U3

When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, a Class U1 surface shall be steel trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

8.2.3 Remedial Treatment of Surfaces

Any remedial treatment to surfaces shall be agreed with the engineer following inspection immediately after removing the formwork and shall be carried out without delay. Any concrete, the surface of which has been treated before being inspected by the engineer, shall be liable to rejection.

All holes and pockets so formed shall be filled with cement mortar mixed in the same proportions as the fine aggregate to cement of the concrete mix used for that particular

section of the structure. Before patching, the surface to be repaired shall be thoroughly cleaned, wetted, and thinly coated with cement paste prior to receiving the patch.

Excessive honeycombing shall be sufficient cause for rejection of portions of the structure containing such honeycombing. The contractor on receipt of a written order from engineer shall remove and rebuild such portions of the structure at his own expense.

Visible cracking and voids shall also be sufficient cause for rejection of portions of the structure containing such defects.

The SC shall be informed of all defects and any proposed remedial treatment to any concrete surfaces. Concrete surfaces treated or repaired without first being inspected by engineer shall be liable to rejection.

The contractor shall ensure that permanently exposed concrete surfaces with Class F2, F3, U2 and U3 finishes are protected from rust marks, spillages and stains of all kinds.

8.3 Preparation of Formwork before Concreting

Before concreting, all forms shall be thoroughly cleaned out, free from sawdust shavings, dust, mud or other debris.

The inside surfaces of forms shall, except for permanent formwork, be coated with an approved non-staining form oil or other approved material to prevent adhesion of the concrete.

Such release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not come into contact with the reinforcement or prestressing tendons and anchorages. For any exposed surface only one (1) release agent shall be used throughout the entire area.

All formwork shall be inspected by the engineer after preparation and immediately prior to depositing concrete and no concrete shall be deposited until approval of the formwork has been obtained from the engineer.

8.4 Removal of Formwork

The contractor shall inform the engineer and obtain his approval before striking any formwork, but such approval shall not relieve the contractor of his responsibilities for the safety of the work.

The removal shall be done in such a manner as not to damage the concrete, and shall take place at times to suit the requirements for it's curing.

Where the concrete compressive strength is confirmed by tests on concrete cubes stored under conditions that simulate the field conditions, formwork supporting concrete in bending may be struck when the cube strength is 10 N/mm² or twice the stress to which it will be subjected, whichever is the greater. In the absence of such tests, the minimum periods between concreting and the removal of forms are given in Table 13 below.

TABLE 13 MINIMUM PERIODS BETWEEN CONCRETING AND REMOVAL OF FORMS

Vertical faces of beams, wall columns, piles, foundation plinths and precast items.	1 days
Underside of slabs	7 days
Underside of beams	7 days
Removal of props – beams and main slabs	16 days

The periods stated above are based on the use of ordinary Portland cement. They may be changed if other types of cement are used, subject to the engineer 's agreement.

For prestressed in situ decks, temporary supports shall not be removed until the deck is stressed.

Where it is intended that formwork is to be reused, it shall be cleaned and made good.

Following the removal of formwork, no further loads shall be imposed upon concrete until at least after the completion of the curing period or until the concrete shall have attained sufficient strength to safely withstand such loads. Full design loads shall not be applied to any structure until all load bearing concrete is at least twenty eight (28) days old.

8.5 Permissible Tolerances

The permissible tolerance of formed and unformed surfaces for the various classes of finish specified in Sub-section 8.2.1 and 8.2.2 shall not exceed the limits shown in Figure 1 and Table 14.

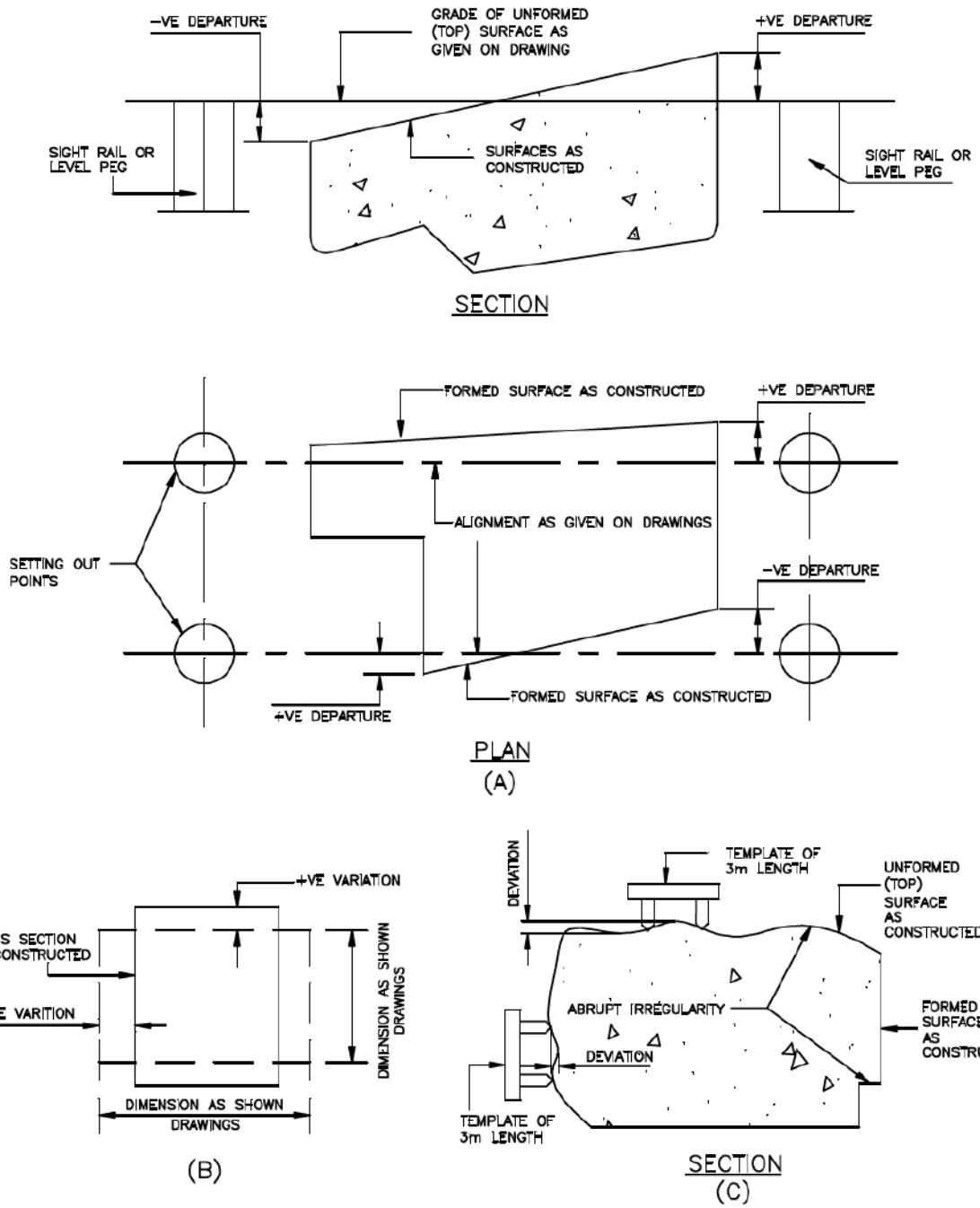


FIG. 1 : ILLUSTRATIONS OF TYPES OF IRREGULARITY LISTED IN TABLE 13

(A) DEPARTURE FROM ALIGNMENT AND GRADE SHOWN ON DRAWINGS
(B) VARIATIONS IN CROSS-SECTIONAL DIMENSIONS
(C) DEVIATIONS FROM TEMPLATE AND ABRUPT IRREGULARITIES

TABLE 14 - PERMISSIBLE TOLERANCES FOR VARIOUS CLASSES OF FINISH

TYPE OF STRUCTURE	TYPE OF IRREGULARITY (See Figure 1)	TOLERANCES (mm) Type of Finish	
		Formed F1 F2 F3	Unformed U1 U2 U3
In situ buried concrete in foundations, ground beams, retaining walls, etc.	Departure from alignment and grade as shown on the Drawings	±13 - -	±13 - -
	Variations in cross sectional dimensions	±13 - -	- - -
	Abrupt		
	Deviation from template in long dimensions	±13 - -	±13 - -
		±13 - -	±13 - -

9.0 WATERTIGHT OF WATERPROOFING CONCRETE

Using a sufficiently low water cement ratio in a concrete mix, the concrete should be able to produce a low porosity concrete that is sufficiently watertight. Alternatively, several proprietary chemicals often termed “integral water proofers” are available as admixtures for use in watertight or waterproofing concrete mixtures.

All additives to watertight or waterproofing concrete shall have the engineer’s approval in writing before its use is permitted. Where approved, watertight or waterproofing additives shall be used strictly in accordance with the manufacturer’s procedure, specifications and requirements. In addition, watertight or waterproofing admixtures being considered for use should be chloride free and meet applicable requirements as presented in Sub-section 2.4.

Workmanship for the watertight construction shall comply with the requirements of BS 8007. Works method statement is to be submitted for the engineer’s review and approval prior to the construction and shall include among others, location of construction joints, joint preparation, concrete handling and curing.

Concrete water tanks subjected to water tightness test and criteria of acceptance shall be in accordance to Clause 9.2 of BS 8007.

The concrete at the joints should be bonded with that subsequently placed against it. Concrete should not be allowed to run to a featheredge, and vertical joints should be formed against a stop end. Particular care should be taken when forming the joints. Concrete construction joint

is not permitted at the areas where watertight concrete is to be used, except at swimming pool. Construction joint at swimming pool shall be provided with approved waterstop.

The surface of the first pour should be roughened to increase the bond strength and to provide aggregate interlock. With horizontal joints, the joint surface should be roughened without disturbing the coarse aggregate particles by spraying the joint surface; approximately 2h to 4h after the concrete is placed with a fine spray of water and/or brushing with a stiff brush. Vertical joints can be treated similarly, to enable the joint surface to be treated after the stop end has been removed.

If the joint surface is not roughened until the concrete has hardened, the larger aggregate particles near the surface should be exposed by sandblasting or by applying an engineer align hammer or other mechanical device. Power hammers should not be used as they may damage or dislodge aggregate particles so reducing, rather than increasing the capacity of the joint to transfer stresses.

Care should be taken that joint surface is clean immediately before the fresh concrete is placed against it. It may need to be dampened prior to the new concrete being placed to prevent excessive loss of mix water into it by absorption. Particular care should be taken in the placing of new concrete close to the joint to ensure that is has an adequate fine content and is fully compacted and dense.

10.0 PRECAST CONCRETE CONSTRUCTION

10.1 Manufacture Off Site

10.1.1 After the method of manufacture has been approved, no changes shall be made without approval without the approval of the S.O.

10.1.2 The Contractor shall inform the S.O in advance of the date of commencement of manufacture and casting of each type of precast concrete component.

10.1.3 When the S.O requires tests to be carried out, none of the precast concrete components to which the test relate shall be dispatched to the site until the test have been completed the result approved by the S.O.

10.1.4 All precast concrete components shall be indelibly marked to show the identification marking as specified in the Drawing, the production batch on which they were manufactured and the date on which the concrete was cast. If the components are symmetrical, the face that will be uppermost when the member is in its correct position in the work shall be clearly identified.

10.2 Storage

10.2.1 When the precast concrete components are stored, they shall be firmly supported on at the points specified in the Drawing. No accumulation of trapped water and deleterious matter shall be allowed in the components. Care shall be taken to avoid rust staining and efflorescence.

10.2.2 The precast concrete components shall be stacked in such a manner that their removal in correct order of age is facilitated.

10.3 Handling and Transport

The precast concrete component shall be lifted only at the points specified in the Drawing or otherwise approved by the S.O and shall be handle and placed without impact. The method of lifting, the type of equipment and transport to be used, and the minimum age of the components to be handled shall be to the approval of the S.O.

10.4 Assembly and Erection

10.4.1 The method of assembly and erection specified in the Drawing shall be strictly adhered to on site.

10.4.2 Immediately a unit of precast concrete component is in position, and before the lifting equipment is removed, temporary supports or connections between components as necessary, shall be provided. The final structure connections shall be completed as soon as is practicable.

10.5 Forming Structural Connections

10.5.1 For structural purposes, cement mortar shall compose of one (1) part of cement to one (1) part of sand (1:1), mixed with water so that the free water: cement ratio does not exceed 0.4 by weight and cement grout shall have a water: cement ratio between 0.4 and 0.6, or such other proportions as shall be directed by the S.O.

10.5.2 No structural connection shall be made until approval has been given by the S.O.

10.5.3 Unless otherwise approved by the S.O., the composition and the free water: cement ratio of the in-situ concrete or mortar used in any connection and the packing of joints shall be in accordance with the assembly instructions.

10.5.4 Levelling devices shall be released or removed only with the approval of the S.O.

10.5.5 Non load bearing joints between precast concrete components and adjoining structures shall be filled with appropriate grout and/or mortar protected by proprietary sealants and backing rod. They shall be waterproof.

10.5.6 Load bearing joints and connection shall be grouted, mortar packed or concreted. The respective mix design shall be free of lime and chloride. They shall be durable, waterproof, non-shrink and possess strength higher than that of precast concrete. Curing for at least three (3) days shall be provided.

10.5.7 The method of sampling and testing of grout and mortar shall be carried out according to MS 26. The compressive strength shall be determined by crushing test on 100 mm cubes. For each casting day for each grade of grout and mortar, three sample shall be taken from three (3) separate batches. Two (2) cubes shall be cast from each sample for testing at seven (7) and 28 days. The appropriate strength requirement shall be considered to be satisfied if the average strength is greater than specified characteristic strength.

10.5 Protection

At all stages of construction, precast concrete components and other concrete associated therewith shall be properly protected to prevent damage to permanently exposed surfaces, especially arises and other decorative features.

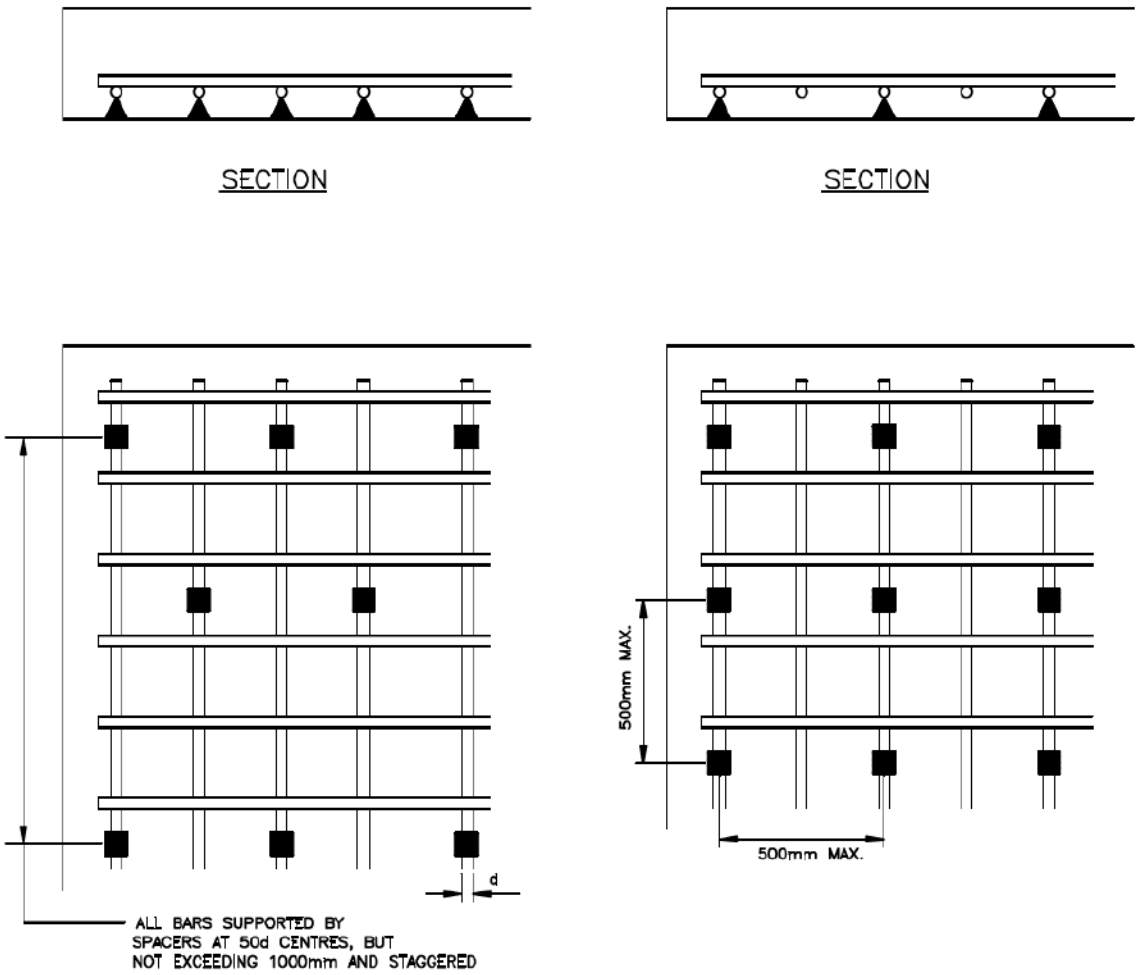
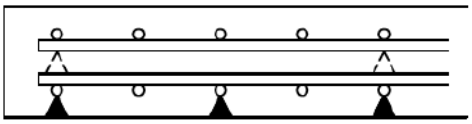
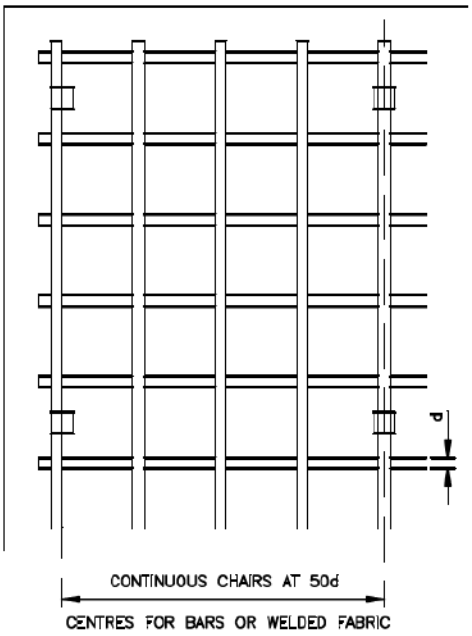


DIAGRAM 1. SPACER FOR BOTTOM REINFORCEMENT IN SLABS



SECTION



PLAN

KEY

SIDE VIEW OF SPACER

END VIEW OF CONTINUOUS CHAIR

PLAN VIEW OF CONTINUOUS CHAIR

DIAGRAM 2. CONTINUOUS CHAIRS FOR TOP REINFORCEMENT IN SLABS WITH BOTTOM REINFORCEMENT

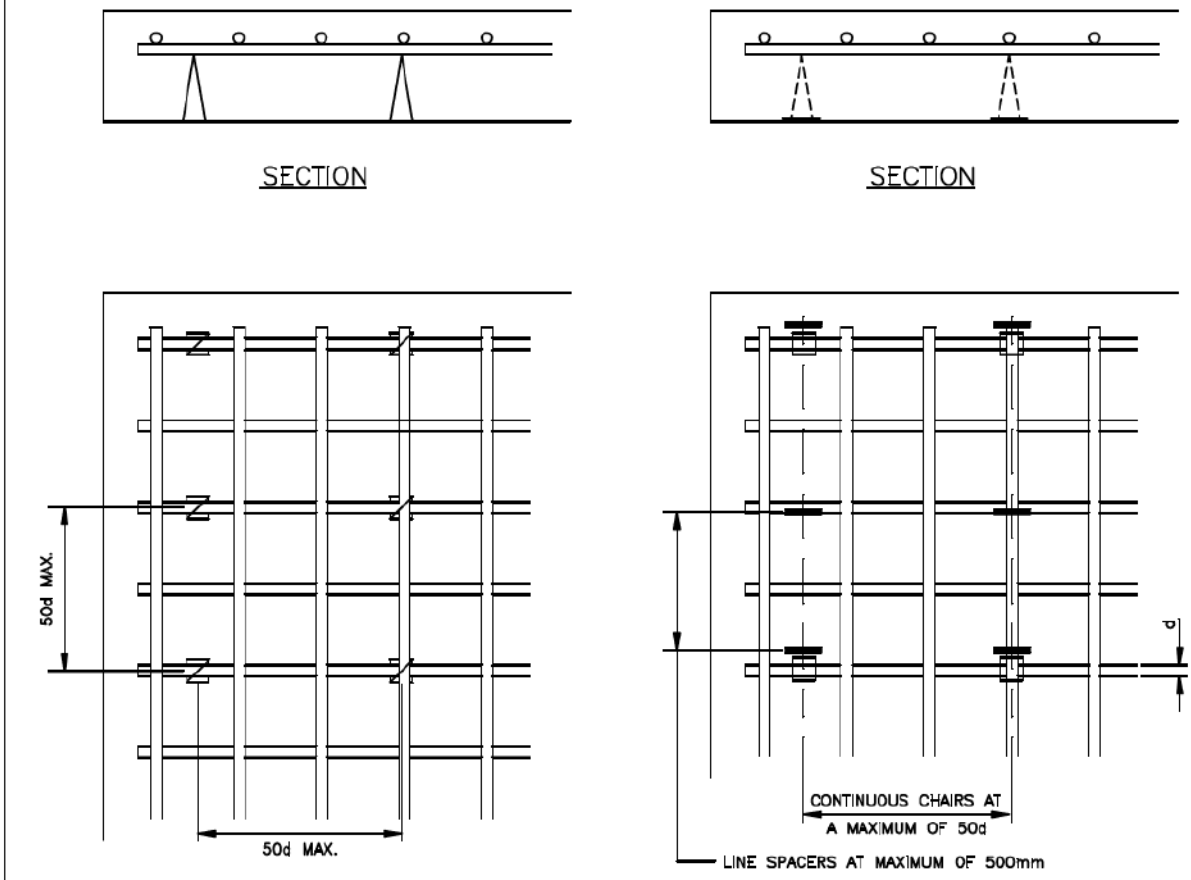
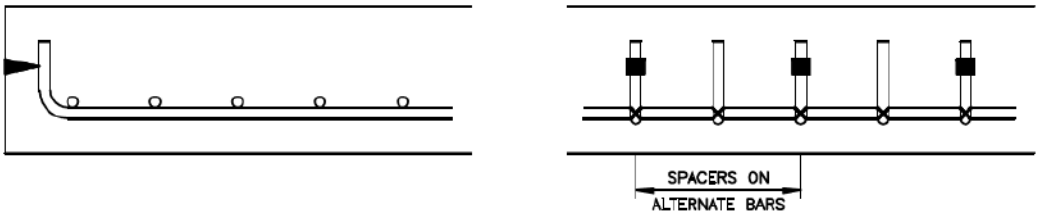
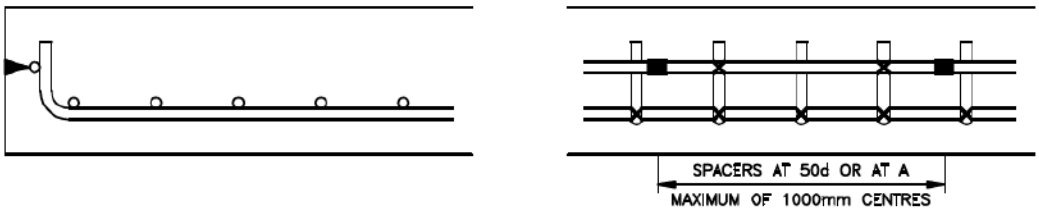


DIAGRAM 3. CHAIRS FOR TOP REINFORCEMENT IN SLABS WITHOUT BOTTOM REINFORCEMENT



SECTION ELEVATION

a) WITHOUT HORIZONTAL REINFORCEMENT



SECTION ELEVATION

b) WITH HORIZONTAL REINFORCEMENT

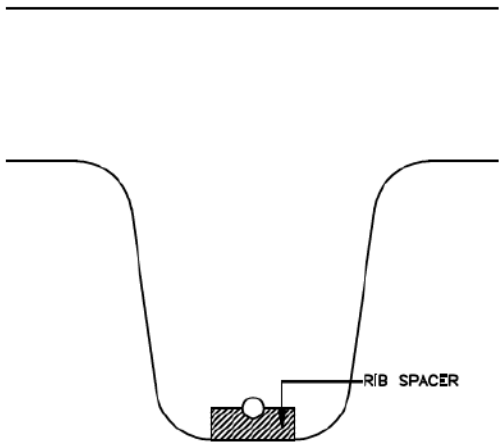
KEY

× WIRE TIE

■ PLAN VIEW OF SPACER

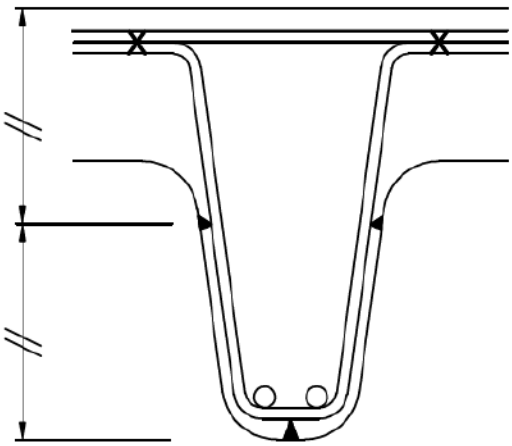
▲ SIDE VIEW OF SPACER

DIAGRAM 4. SPACERS FOR SLAB EDGES



ONE MAIN BAR

a) WITHOUT LINKS



MORE THAN ONE BAR

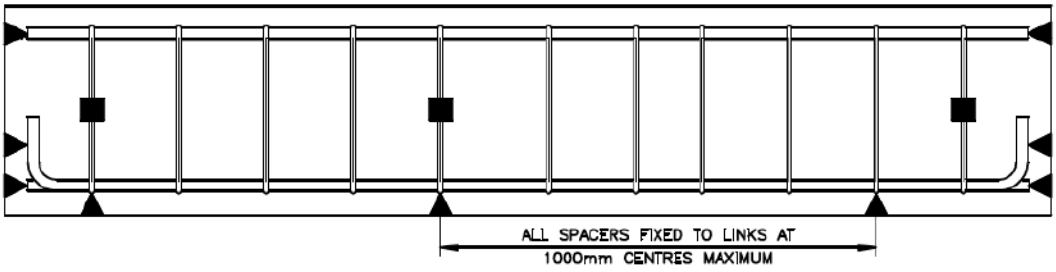
b) WITH LINKS

KEY

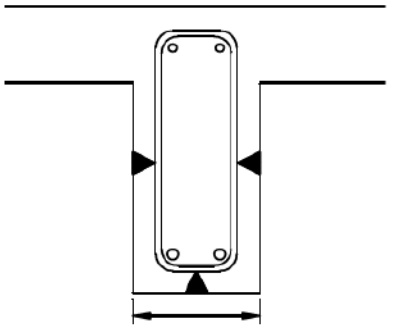
X WIRE TIE

▲ SIDE VIEW OF SPACER

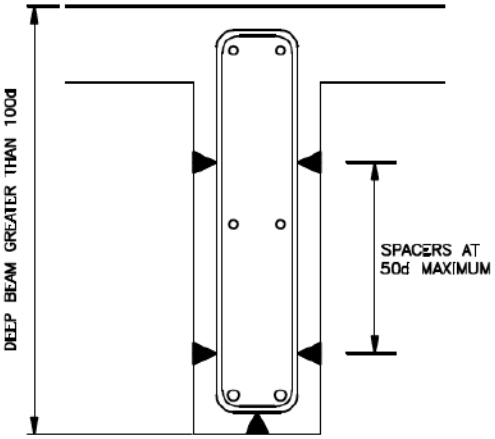
DIAGRAM 5. SPACERS FOR RIBBED SLABS



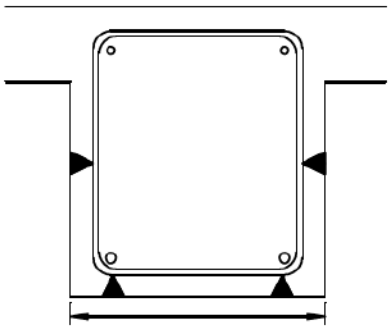
a) BEAM ELEVATION



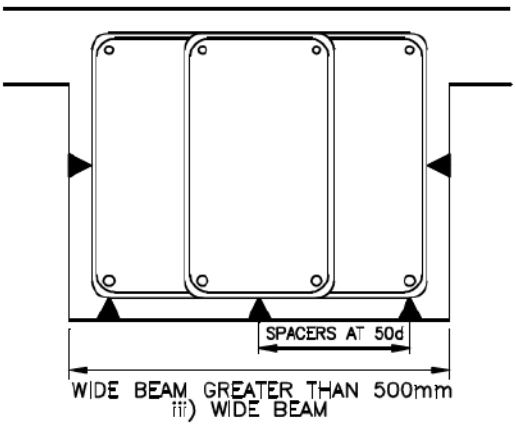
NARROW BEAM LESS THAN 250mm, ONE SPACER
i) NARROW BEAM



b) SPACERS FOR THE SIDES
OF DEEP BEAMS



NORMAL BEAM 250mm TO 500mm, TWO SPACERS
ii) NORMAL BEAM



WIDE BEAM GREATER THAN 500mm
iii) WIDE BEAM

c) SPACERS FOR THE BOTTOM OF BEAMS

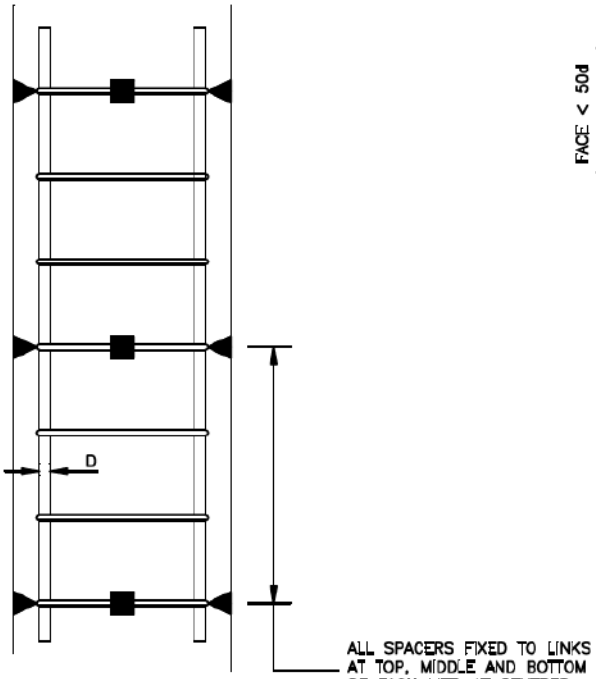
KEY

■ PLAN VIEW OF SPACER

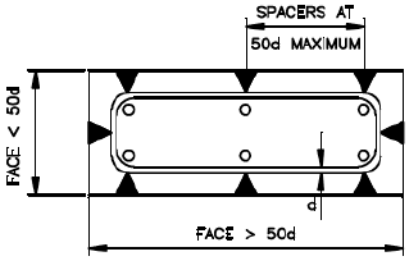
▲ SIDE VIEW OF SPACER

d LINK SIZE

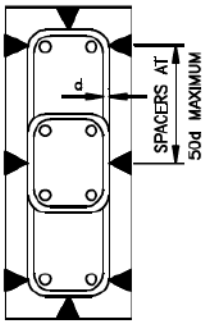
DIAGRAM 6. SPACERS FOR BEAMS



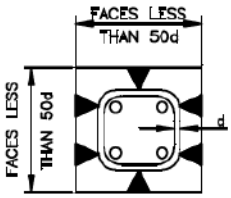
a) SPACERS ALONG COLUMN



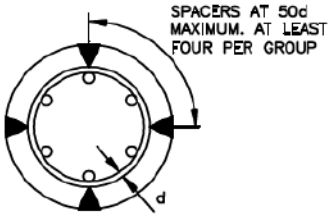
c) WIDE COLUMNS



d) DOUBLE LINKS



b) SMALL COLUMNS



e) CIRCULAR COLUMNS

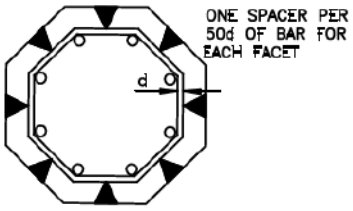
KEY

■ PLAN VIEW OF SPACER

▲ SIDE VIEW OF SPACER

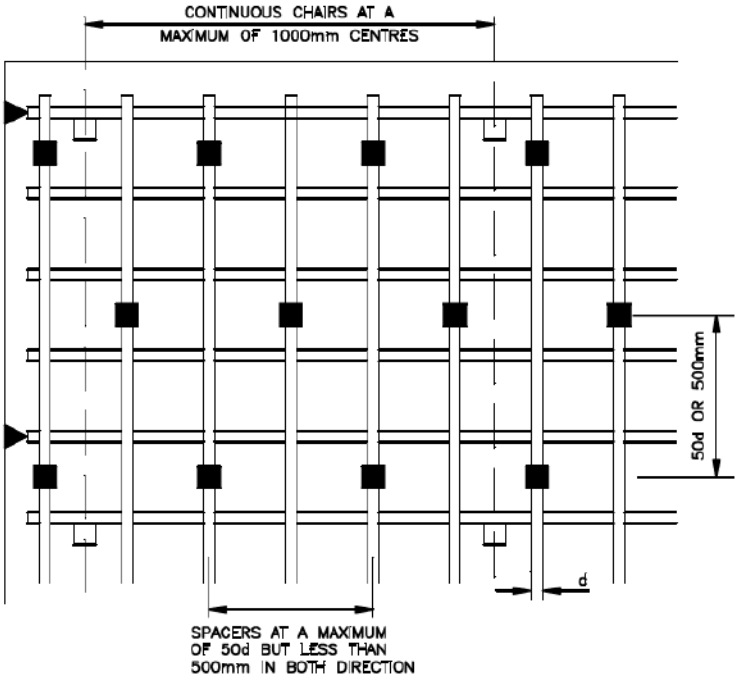
d LINK SIZE

D SIZE OF MAIN BARS

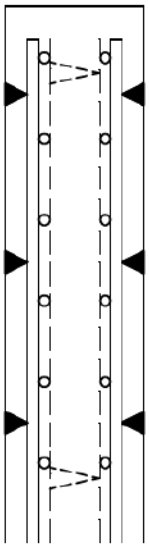


f) MULTIFACETED COLUMNS

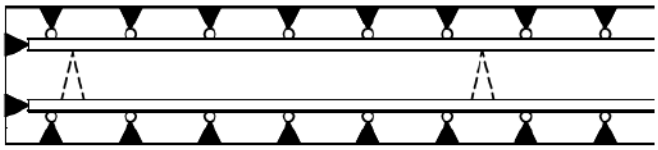
DIAGRAM 7. SPACERS FOR COLUMNS



ELEVATION



SECTION



PLAN

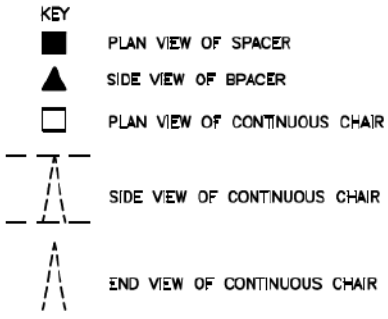


DIAGRAM 8. SPACERS FOR WALLS

STRUCTURAL STEELWORK

CONTENTS

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STRUCTURAL STEELWORK

1.0 STEELWORKS

1.1 General

1.1.1 Scope

This section gives requirements of materials, fabrication, erection and corrosion protection of structural steelwork.

1.1.2 Fabrication Drawings

The contractor shall, based on the Drawings, prepare such fabrication drawings as are necessary for the proper fabrication, assembly and erection of the steelwork. All fabrication drawings are to be submitted to engineer for approval. In the event of any apparent ambiguity, contradictions or deficiency in the information supplied, the contractor shall obtain written clarification or further information from engineer.

Design and detailing carried out by the contractor shall be in accordance with the latest revisions of B.S. 5950 and this Specification, unless otherwise directed by engineer.

1.1.3 Alternative Proposals

The contractor shall satisfy himself as to the practicability of the details and connections shown on the Drawings, and may put forward alternative proposals. Such proposals shall be submitted to engineer for approval at least six weeks before fabrication of that particular part of the Permanent Works is programmed to start and shall not be used for fabrication purposes until approved in writing by engineer.

1.2 Materials

1.2.1 Structural Steel

Structural steel shall comply with BS 4360 grades S275 and S355 as indicated on the Drawings. In addition, structural steel hot rolled sections shall comply with the requirements of BS 4848 and structural steel hot rolled hollow sections with BS 4848 Part 2. The maximum carbon equivalent value for each grade of steel shall not exceed the values specified in BS 4360.

1.2.2 Ultrasonic Testing

Ultrasonic testing shall be carried out by the contractor in the presence of engineer as a means of confirming the quality of the steel plate with regard to lamellar defects and inclusion clusters.

The equipment used and the method of testing shall be in accordance with BS 5996.

The contractor shall submit to engineer, copies of all mill test certificates for materials to be used in the works. Each piece of steel shall be identified by the manufacturer's name or trademark and batch number showing direct correlation to the mill test certificates.

The steel shall be new, well and clearly rolled to the dimensions, sections and weights specified. It shall be free from cracks, surface flaws laminations and other defects.

1.2.3 Black Bolts, Nuts and Washers

Black bolts and nuts shall comply with BS 4190 and shall be to grade 4.6. High strength bolts shall conform to BS 3692 and shall be grade 8.8. Washers shall comply with BS 4320. Taper or other specially shaped washers shall be made of steel or malleable cast iron.

1.2.4 High Strength Friction Grip Bolts

High strength friction grip bolts, nuts and washers shall comply with BS 4395 and shall be General Grade bolts unless shown otherwise on the Drawings.

1.2.5 Sherardizing of Bolts

All bolts etc. with their nuts and washers shall be class 1 sherardized to BS 4921 except for bolts with their nuts and washers which will be built into concrete.

1.2.6 Cast Steel

Steel castings shall be true and clean and shall comply as regards quality and tests (unless otherwise specified) with BS 3100 for the steel most appropriate for the duty.

1.2.7 Steel Forging

All steel forging shall comply with BS 4670 stainless steel forging where specified shall be to grade 410S21/P to BS 970.

1.2.8 Cast Iron

Spheroidal or nodular graphite cast iron shall comply with the requirements of BS 2789.

1.2.9 Shear Connectors

Shear connectors shall be of the headed stud type with a head diameter not less than 1.5 times the diameter of the shank. The connector material shall be steel with a minimum yield strength of 385 N/mm^2 and a minimum tensile strength of 495 N/mm^2. The minimum elongation of a tensile test specimen at break shall be 18%.

1.3 Workmanship

1.3.1 General

Structural steelwork shall be in accordance with BS 5950.

1.3.2 Handling of Steel

All plates, sections and fabricated pieces shall be handled and slung in such a manner as to avoid twisting, over-stressing and damage of any nature.

1.3.3 Holes

The diameter of holes for counter-sunk bolts and black bolts shall generally be 2mm larger than the nominal diameter of the bolt as manufactured except where close tolerance or turned barrel bolts are specified. All holes shall be drilled in the solid and all burrs shall be removed.

Where it is not practicable to drill through the entire thickness of parts to be connected in one operation the separate parts shall be drilled through hard steel bushes and reamed if necessary.

Unless otherwise specified by engineer holes for high strength friction grip bolts shall comply with the requirements of BS 4604.

1.3.4 Making Good

No burning-in, welding, filling or plugging of defective work will be permitted, except with the written sanction of engineer.

1.3.5 Washers

All bolts shall be provided with washers under the heads and nuts, and washers shall be appropriately tapered on the insides of flanges or beveled structural steel sections. In all cases bolts shall project not less than one full thread through the nut after tightening up.

1.3.6 Levelling and Straightening

All plates, bars and rolled sections shall be carefully trimmed, straightened and taken out of winding by pressure before they are drilled. Heating of rolled sections and plates for purposes of straightening will not be permitted, unless the procedure is fully approved by engineer.

1.3.7 Preparation of Edges

Edges of plates and ends of rolled sections shall be finished by cold sawings, planning or milling or machine flame cutting as specified herein. Hand flame cutting or shearing will not be permitted.

When flame cutting is used the hardness of the cut edge shall not exceed 350 HV 30 of BS 427. Flame cutting procedure trials shall be carried out as specified in Sub-Clause 1.4.15.

1.3.8 Fitting of Stiffeners

Where fittings of stiffeners are required they shall be machined so that the maximum gap over 60% of the contact area does not exceed 0.25mm.

1.3.9 Tolerances

Dimensional tolerances permitted for rolled and build up sections are as BS 5950 except where otherwise shown on the Drawings.

1.3.10 Marking

All parts of the structures shall be marked to an approved reference system designating their position in the completed assembly. All marks shall be maintained until after completion of site erection.

In the marking out of plates no hard stamping or center punch markings will be permitted, except where the mark is removed by the forming or drilling of a hole.

Plate identification markings from the mills shall be carefully preserved and transferred so that any plate can be identified in its place in the structure.

The contractor shall supply engineer with full information in this respect.

1.3.11 Protective Coating

All steelwork shall be given the specified protective coating, and with the exception of bolted connections as shown on the Drawings, all steelwork shall be fully fabricated prior to the application of the protective coating.

The protective coating shall be protected as specified during the handling, transport, storage and erection of the steelwork.

1.3.12 Protection of Machined Surfaces

All machined surfaces are to be coated with 'lanolin' grease and provided with an approved form of mechanical protection to avoid damage during transit.

1.3.13 Method of Assembly and Erection

The contractor shall submit his proposed method of assembly and erection to engineer for approval before commencing the works. Such approval will not relieve the contractor of his responsibility to transport, stack, assemble and erect the structures without damage, destruction or over-stressing. Any member so damaged shall be replaced or rectified as directed by engineer.

1.3.14 Temporary Attachments

No toggles, strongbacks or other temporary fixtures shall be attached to any part of the structure during fabrication or erection without the prior approval of engineer.

1.3.15 Erection at Fabrication Works

Structures shall be erected in complete units at the contractor's works to demonstrate alignment and fit in accordance with BS 5950. In the case of repetitive panel construction, the requirement for full trial erection may be relaxed at the sole discretion of engineer where it can be demonstrated that the fabrication processes result in compliance with all the dimensional requirements as specified herein.

1.3.16 High Strength Friction Grip Bolts

High strength friction grip bolts shall be used in accordance with BS 4604 Part I.

1.3.17 Preparation of Faying Surface

The faying surfaces at friction grip bolted connections shall be shot blasted as specified herein. They shall then be protected from contamination by an approved coverage of self-adhesive waterproof membrane such as oil, paint or any other material. Such protection shall only be removed immediately before assembly of the connection.

In the event of plate areas at connections becoming contaminated such areas shall be blasted to bare steel and re-sprayed and then re-protected as described above.

1.4 Welding and Flame Cutting

1.4.1 General

Welding shall be by metal-arc process complying with BS 5135. The use of welding processes other than those covered by BS 5135 shall be subject to the approval of engineer.

The general welding programme for shop and site welds, including particulars of the preparation of fusion faces, the methods of preheating where required, the method of

making the welds, and the type of electrodes shall be submitted to engineer for his approval before the work is put in hand. No departure from the agreed welding programme or from the details shown on Drawings shall be made without the agreement of engineer. Electrodes and fluxes shall be so chosen that the properties of the deposited metal are not inferior to that of the parent metal.

1.4.2 Arc Welding Materials

Consumables for use in the manual metal arc welding of mild steel and medium tensile steel shall be covered rods in accordance with BS 639 and suitable for the work on which they are to be used.

1.4.3 Electrodes Storage

Electrodes and fluxes shall be stored and used in accordance with the manufacturer's instructions, but at a temperature not less than 10°C. Engineer shall have access to inspect the store and may reject for use electrodes which are in any way unsuitable.

1.4.4 Butt Welds

Butt welds shall be continuous complete-penetration welds made between prepared fusion faces.

In the fabrication of built-up assemblies all butt welds in each component shall be completed, wherever possible, before the final assembly.

Where automatic or semi-automatic processes are approved by engineer for use, back gouging of the deposited weld will be required unless engineer is satisfied that the root is free from imperfections.

Butt welds shall be ground smooth and flush where directed by engineer. The final grinding shall be carried out in the direction of the applied stress. Any loss of parent metal resulting from this process shall not be greater than that allowed for in the correction of minor surface defects specified in BS 4360.

1.4.5 Tack Welds

Tack welds shall be of the same quality and size, and formed under the same conditions as the first run of the main weld, which latter shall fuse completely with the end of the tack welds to form a regular profile. Tack welds shall be at least 50mm long.

1.4.6 'Run-on' and 'Run-off' Plates

At the ends of butt welded joints 'run-on' and 'run-off' plate extension pieces shall be used. 'Run-on' plates and 'run-off' plates shall comply with the following requirements:

(i) One pair of 'run-on' plates and one pair of 'run-off' plates prepared to the same thickness and profile as the parent metal shall be attached by clamps to the start and finish of all welds;

(ii) Butt welds shall extend at full weld profile for a minimum distance of 25mm into both the 'run-on' and 'run-off' plates;

(iii) When removing the 'run-on' and 'run-off' plates by flame cutting, the cuts shall not be nearer than 6mm to the sides of the parent metal and the remaining metal shall be removed by grinding or some other methods approved by engineer.

1.4.7 Production Test Plates

Approximately one in five pairs of 'run-off' plates for transverse butt welds shall be production test plates. The welds where production test plates are required will be specified by engineer on receipt of the contractor's working or shop drawing. The combined size of each pair of production test plates shall be adequate for the number and size of specimens to be tested. The material quality of their rolling direction shall be the same as that of the plates to be welded. On completion of the welds the 'run-off' production test plates shall not be removed until they have been marked in a manner agreed by engineer to identify them with the joints to which they are attached. The cost of welding, detaching and testing these test plates shall be included in the rates.

1.4.8 Assembly of Pieces

Before welds are made the assembled parts shall be examined by gauges to ensure that 'fit-up' of the parts is correct. Unless otherwise approved by engineer, all welds shall be made in the down-hand or horizontal-vertical position. A tolerance of 1mm may be allowed in the alignment of butt welded joint faces and edges.

1.4.9 Qualifications and Testing of Welders

Welding qualification records issued by SIRIM or other approved testing Authority for each welder shall be submitted to engineer before commencement of the work.

Evidence of competence of all welding operatives and supervisors shall be provided in accordance with BS 4872 Part 1.

Routine re-testing of welding operators may be required at six monthly intervals.

Engineer may at any time call for a repeat of all or part of the initial test for any welder where work is found to be below standard and permission already granted to employ such welder on the Works will be withdrawn if the results of such test are unsatisfactory.

1.4.10 Supervision of Welders

The contractor shall appoint competent welding supervisors to ensure that all welding is carried out in accordance with the Specification. No welding shall be carried out except under the direction of a supervisor.

The contractor shall satisfy engineer of the qualifications and competency of the welding supervisors whose employment on the works shall be subject to engineer 's approval.

1.4.11 Records of Welds

Except where agreed by engineer, a record in the form approved by engineer shall be kept by the contractor to enable all welds of all types to be identified with the welders responsible for the work, but such record shall not be made by hard stamping.

1.4.12 Welding Plant

The welding plant shall be capable of maintaining at the weld, with minimum fluctuation, voltage and current within the range specified by the manufacturer for the type of electrode being used and the welding position adopted. The contractor shall supply for the use of all personnel engaged in welding, suitable instruments for verifying voltage and current, and these shall be available for use by engineer when required.

1.4.13 Weather

No welding shall be carried out when the quality of the complete weld may be impaired by weather conditions including high winds, blowing sand or dust, or airborne moisture. Wind shields shall be used when welding out of doors. All protection against weather shall be to the satisfaction of engineer.

1.4.14 Inspection

No painting of welds will be permitted until after inspection and approval by engineer. Each approved welder shall mark all his work immediately upon completion. Where more than one welder has been involved in the weld, each shall apply his mark.

1.4.15 Welding and Flame Cutting

Before fabrication is commenced, welding and flame cutting procedure proposals shall be submitted to engineer for approval. Trials shall be carried out using representative samples of materials to be used in the work, and no welding or cutting of materials for the Permanent Works shall commence until engineer has approved the contractor's proposed procedures. Such approval shall not relieve the contractor of his contractual responsibilities and the procedures established from the trials shall be strictly followed. Should the contractor wish to modify either welding or flame cutting procedures similar trials of the new proposals shall be carried out and engineer 's approval to them sought and obtained before the new procedures are used.

The samples of materials shall be selected and marked by engineer when the materials for the work are inspected at the mills. The tests shall be carried out at the contractor's works.

Trials on material 20mm thick shall be taken to include all material up to but not exceeding 20mm thick. Trials on material 32mm thick shall be taken to include material over 20mm and up to but not exceeding 32mm thick. Material over 35mm thick shall be tested for every thickness increment of 5mm.

The welding and flame cutting trials shall demonstrate to the satisfaction of engineer. The procedure to be adopted in the fabrication of the work and shall include:

(i) Welding procedure in accordance with BS 5135.

(ii) Heat control techniques to ensure that the flame cut surfaces of steel are free from cracks, local hardness, and any other defects which would be detrimental to the finished work.

The trials shall include specimen weld details representative of the actual construction which shall be welded in a manner simulating the most unfavorable conditions liable to occur in the particular fabrications. After welding the specimens shall be held at a temperature not less than 10^{o}C for a period of not less than seventy two (72) hours and shall then be sectioned and examined for cracks and other defects.

1.4.16 Testing of Trial Procedures

The following groups of tests in relation to trial procedures shall be carried out in accordance with Sub-Clause 1.4.17.:

(i) Butt Welds

- Transverse tensile test
- Transverse bend tests
  (separate tests shall be performed in each case with the root of the weld in tension and compression respectively)
- Macro examination test

(ii) Fillet Welds

- Fillet weld fracture test
- Macro examination tests

1.4.17 Testing of Welding

The tests and trials detailed in Sub-Clauses 1.4.15 and 1.4.16 shall be carried out by the contractor in the presence of engineer as specified in BS 4870. In addition, the test results of welded joints shall not be inferior in any respect to the test requirements for the parent metal. The requirements of Sub-Clauses 1.4.18 to 1.4.20 shall also be met.

1.4.18 Requirements of Procedure Trials

In respect of Procedure Trials (Sub-Clause 1.4.16) the following requirements shall be met: -

(i) Tensile and Bend Tests

Should any one of the weld joint test pieces selected for transverse tensile and transverse and longitudinal bend tests fail to comply with the test requirements applicable to the parent metal of the joint represented by the

test, two additional test pieces shall be taken from the joint material represented by the test. Both shall then comply with the test requirements in order to qualify for acceptance.

(ii) Macro examination and fillet weld fracture tests

In the case of the macro examinations and fillet weld fracture tests any imperfection such as cracks, lack of penetration or lack of fusion shall be considered as injurious defects and may result in the rejection of the procedures adopted in the trials. The contractor will be required to carry out further trials using revised procedures and further tests to the satisfaction of engineer.

1.4.19 Requirements of Production Tests

In respect of Production Tests (Sub-Clause 1.4.7) the following requirements shall be met: -

(i) Production Test Plates

The run-off production test plate specified in Sub-Clause 1.4.7 shall be cut out to enable up to two complete sets of test specimens to be obtained.

One transverse bend test, and one transverse tensile test shall be carried out from each test piece as part of the routine testing of the weld by the contractor. The tests shall be carried out by the methods described in BS 709 and the results notified promptly to engineer.

(ii) Tensile and Bend Tests

Should any one of the weld joint test pieces selected for transverse tensile and transverse bend tests fail to comply with the test requirement applicable to the parent metal of the joint represented by the test, additional specimens shall be cut from the same production test plates and the tests repeated. Should either of the additional tests fail to comply with these requirements the joint shall be rejected.

(iii) Re-welding and Re-testing

In the event of failure to meet the test requirements the welded joint represented by the tests shall be completely cut out. The joint shall then be re-welded and retested.

1.4.20 Non-destructive testing

Ultrasonic, Radiographic and other approved types of non-destructive testing shall be carried out according to Table 1.

The radiographs shall become the property of the Employer. Arrangements for the execution of all testing shall be the contractor's responsibility. Written reports in duplicate of the results of all testing shall be handed to engineer not less than 48 hours

after the testing has been done. The reports shall include sketches showing the location and extent of all defects.

Engineer 's approval to the operatives carrying out the inspections and equipment which they use and examination of all welding shall be obtained before any inspection and examination is carried out.

Table 1 Radiographic and Ultrasonic Testing

Location	Type of Weld	Type Test	Extent of Test
Plate Girders			
All transverse flange joints	Butt	Radiograph	100%
All transverse web joints	Butt	Radiograph	500mm adjacent to both flanges
All other joints	All types	Radiograph Magnetic crack detector or dye penetrant	10% of all welds determined by engineer.
Box Girders			
All transverse flange or web joints	Butt	Radiograph	100%
All other joints	All types	Radiograph Magnetic crack detector or dye penetrant	10% of all welds determined by engineer.
"T" Connectors at Bracing and Cross girders and internal "T" Butt joints with full strength welds	"T" Butt	Ultrasonic to be performed not earlier than 72 hours after welding	Complete weld

1.4.21 Repairs to Welds

If engineer is of the opinion that defective welds can be repaired, the defective welds may be cut out and repaired by manual metal-arc welding, subject to satisfactory results from any further tests which engineer may order. When a defect is removed the existing weld, on each side of the defect, shall be chipped or machined back in the form of a taper over a length of at least eight times the weld size. The weld shall then be restarted at the top of the tapered slope. On completion the surface of the weld at the start-stop positions shall be ground smooth. Pre-heating for all sections requiring repairs shall be in accordance with BS 5135 and welded using low hydrogen electrodes.

1.4.22 Camber

Camber applied to steel girders shall be of smooth curvature and shall be in accordance with the instructions of engineer as shown in the Drawings.

1.5 Corrosion Protection

1.5.1 Paints for Steel Work

All paints, primers, epoxide, thinners, curing agents and other approved protection materials, hereafter referred to as paints, and cleaning solvents for any protective coating system in this Specification shall be the products of the same manufacturer.

The contractor shall submit details of the manufacturer's system to engineer at least 6 weeks before painting of any steel component is due to start and the system shall not be used for corrosion protection until approved in writing by engineer.

The paints and cleaning solvents shall be furnished in unbroken original containers of not more than twenty five (25) litres capacity bearing the manufacturer's name and identifying code with a clear date of manufacture. Paint which has not been used within the 'shelf life' specified on the container shall be discarded and replaced.

1.5.2 Storage

All paints shall be stored in cool, frost free, dry conditions. Supplies of paint shall be used in the same order in which they are delivered.

1.5.3 Samples

The contractor shall supply to engineer one litre samples of the selected paint, well in advance of their use. Engineer will take samples for testing and analysis from containers of paint in use whenever he so wishes.

1.5.4 Thinning

All paints shall be used as supplied by the manufacturer without thinning or adulteration except where specially allowed under this Specification, when the thinner specified by the manufacturer shall be used.

1.5.5 Data Sheets

The contractor shall submit to engineer copies of the data sheets for all paint materials he proposes to use, together with any identifying codes.

1.5.6 Specialist Sub-contractors

All paints, coats and sprays shall be applied in accordance with the manufacturer's recommendations by an approved painting, coating or spraying sub-contractor proposed by the material supplier. The sub-contractor proposed shall be fully experienced with the material concerned, and he shall employ specialized labour. The material supplier shall carefully supervise and be responsible for all stages of the application work including surface preparation, protection against weather etc. The material supplier shall give to engineer such advice as may be required on all matters relating to standards of materials and workmanship.

1.5.7 Specifications, Variations

Painting shall comply with BS 6150 and BS 5493 and with this specification, but should the material supplier advise that the detailed Specification of the material or method of application should be varied to take account of conditions during the period of application or after, then the contractor shall allow for and take account of such variations as engineer may accept, approve or order.

1.5.8 Blast Cleaning

All steel surfaces to be painted, shall be blast cleaned to remove all rust, mill scale, welding slag, flux spatter and residues and to provide a finish in accordance with BS 7079, in achieving a surface finish of Sa 2.5 as specified in Sub-Clause 1.5.1. Surfaces shall be treated to remove deposits of oil or grease immediately prior to blasting.

Blast-cleaning of steel surfaces shall be carried out generally in covered workshops with adequate lighting, heating and ventilation and in accordance with BS 7079. Blasting of steel surfaces shall not be carried out when the surface temperature is less than 3^{o}C above the dew point, when the relative humidity is greater than 85% or where there is the possibility that the blasted surface may get wet before the first coat of primer is applied.

Approval of the workshops and equipment proposed to be used for blast cleaning shall be obtained from engineer at least six weeks before any blast cleaning is carried out in that workshop.

The abrasive used for blasting shall be free from contamination and any recovered material shall be thoroughly cleaned before re-use. Non-metallic abrasives may only be used with approval of engineer.

Threaded fittings shall be protected by bolts or screwed rods in such a way as to allow blast cleaning up to the edge of the hole and temporary bolts retained for the coating process.

Surface 'shelling' and other imperfections raised by the cleaning process shall be repaired at this stage to engineer's satisfaction.

The contractor shall submit to engineer prior to the commencement of blasting information concerning the proposed size and type of abrasive to be used to meet the requirements of BS 7079.

The blast-cleaned steelwork shall be freed from dust and adherent particles by vacuum or brush before any coating is applied and no member shall be primed or coated until the cleaned surfaces have been inspected and accepted by engineer. Where a longer period than three (3) hours has elapsed since cleaning or where blasted surfaces have, in the opinion of engineer, deteriorated, they shall be re-blasted immediately prior to painting.

A sample blast-cleaned steel panel measuring not less than 150mm x 150mm x 6mm adequately protected by sealed clean polythene wrapping, shall be submitted for approval to engineer for each blast-cleaning method.

1.5.9 Surfaces to be Clean and Dry

All surfaces shall be cleaned and free from grease when primer, paint, coat or spray is applied. Degreasing with solvents compatible with the paint, coat or spray shall be done at any stage as necessary. All surfaces shall be dry immediately before primer, paint, coat or spray is applied and shall be kept dry for as long as is necessary for the paint, coat or spray to harden, set or cure to such an extent it can be wetted without adverse effect.

1.5.10 Damage or Deterioration of Primed Surfaces

Any primed surface damaged by subsequent processes or which has deteriorated, to an extent that proper adhesion of the paint, coat or spray may not be obtained, shall be blast cleaned again, and reprimed if necessary before the paint, coat or spray is applied.

1.5.11 Humidity during Coating

Painting, coating or spraying shall not be carried out when the humidity in the vicinity of the surface is such that condensation could readily occur on the surfaces either immediately before or during the application or when the humidity could have detrimental effect.

1.5.12 Multiple Coats

All paints, coats or sprays shall be applied in as many layers and at such intervals as necessary to provide the specified minimum finished dry film thickness without runs, sags or other blemishes and to ensure the proper curing, drying and hardening of the layer.

When more than one layer is applied to a surface each layer shall be of a different colour to its predecessor.

1.5.13 Site Painting

Except for internal surfaces of boxes or steelwork which shall subsequently be in contact with concrete, steelwork shall be supplied to site with the primer and at least one coat of high build micaceous iron oxide/chlorinated rubber paint applied as a travel coat. In the case of members launched on rollers the travel coat may be omitted on the bottom flanges of the girders which will be in contact with rollers during launching.

Prior to application of the final site coat any painted surface which has been damaged shall be repaired by reapplying the full paint treatment as herein specified for the main work or as advised by the material supplier.

1.5.14 Application and Temperature

The painting processes shall be so separated from blast-cleaning that no dust, detritus or grit falls on to fresh paintwork or insufficiently hardened coats.

All protective paint, coat or spray shall be applied by stiff brush or airless spray and the temperature during application shall not generally drop below 10°C unless special precautions are taken.

1.5.15 Handling Coated Steelwork

Slings, ropes and chains employed for handling painted, coated or sprayed steelwork shall be rubber sheathed or similarly covered to avoid damage to the protection system. Steelwork shall not be stacked with painted, coated or sprayed surfaces in direct contact.

1.5.16 Protection of Coated Surfaces

The contractor shall submit with his tender his proposals for protecting the shop-applied paint, coat or spray before dispatch from the paint or spray shop. This protection shall be of a standard that the paint, coat or spray will not suffer damage under the normal handling and transport conditions.

Other items of painted, coated or sprayed steel and ironwork shall be similarly protected before dispatch to the Site from the paint or spray shop.

1.5.17 Zinc Primer

The zinc primer, shall be two components epoxy polyamide cured type containing at least 85% zinc content in the dry film. It shall be high flash paint and fast drying.

1.5.18 Main Coats

The main coat shall be an approved micaceous iron oxide pigmentation compatible with zinc epoxy primer. It shall be high build product and capable of indefinite period of over coating.

(i) The minimum requirements of the coatings to be specified for steel members protected from weathers: -

Total coats = 3

Shop Applied

		Min D.F.T Microns
a)	Blast clean according to BS7079; surface finish Sa 2.5	
b)	Approved Moisture Curing Inorganic Zinc Ethyl Silicate Coating	75
c)	Approved Fast Dry Amine Cured Micaceous Iron Oxide (MIO) Epoxy Coating Recoatable in 1.5 Hours At 30 Degree Celcius	175
d)	Ensure steel work is free from dirt, grease, oil and other contaminants by solvent cleaning and washing with clean fresh water	

Site Applied

e)	Approved Chemically Curing Aliphatic Acrylic Polyurethane Coating	75

1.5.19 Fire Protection

(a) All structural steel works, unless otherwise stated in the Drawings, shall be provided with fire protection to give a minimum fire resistance of two (2) hours as specified in the Fire Protection for Buildings: 1984 for the particular purpose group of building of which it forms part.

(b) The fire protection shall consist of intumescent paint or sprayed vermiculite cement with density of 300-400kg/m^3. The mix proportions and method of application will be as specified by the manufacturer and approved by engineer. The contractor shall ensure that the fire protection material is compatible with the paint system used. Otherwise, the contractor may propose alternative system for engineer's approval.

(c) For steel works visible to public and exposed to water, the intumescent paint shall be adopted. For steel work non-visible to public and not exposed to water, the vermiculite cement shall be used.

(d) 50µm thick of zinc rich primer will be applied to all steel works before the application of intumescent paint or vermiculite cement. The thickness of intumescent paint or vermiculite cement shall be computed by the sub-contractor based on manufacturer's recommendation. A 50µm of polyurethane top coat may be required over intumescent paint subjected to architect's requirements.

1.6 Galvanizing

Galvanizing shall be carried out in accordance with B.S. 729 Part 1. All metals to be galvanized shall be of the full dimensions shown or specified and all punching, cutting, drilling, thread tapping, welding and the removal of burrs shall be completed before the galvanizing process commences.

All galvanizing shall be done by the hot dip process with spelter, not less than 98% of which shall be pure zinc. Bolts, nuts and washers shall be completely galvanized including the threads, but galvanizing removed in the course of nut fixing may be replaced with an approved zinc rich paint.

The galvanizing shall be uniform, clean, smooth and as free from spangle as possible. It shall weigh not less than 0.4 kg per square metre of area covered.

All galvanized metal parts shall be protected from damage due to electrolytic action, white rust and abrasion during delivery, storage and erection. Minor damage shall be touched up with an approved zinc-chromate or other approved metallic compound but if, in the opinion of engineer, the damage to the galvanizing is too severe or extensive the part shall be removed and be re-galvanized.

The contractor shall not use fixtures and fittings for metalwork (including pipework) in which dissimilar metals likely to lead to galvanic action are placed in permanent contact with each other.

Unless otherwise specified or directed, galvanized steelwork shall be painted as specified in Sub-section 1.7.

1.7 Painting On Galvanized Steelwork

Before any painting of the protection system as specified in Sub-section 1.5.1, galvanized steelwork shall receive one coat of an etching primer (Dulux AR 565-10045 or equivalent). The etching primer shall be overcoated with grey green chromate primer within two days.

1.8 Performance Guarantee

The contractor shall give a ten (10) year guarantee for corrosion resistance effective from the date of completion of the whole works. The form of guarantee shall be to the satisfaction of the Employer.

Should any corrosion occur during the guarantee period, the contractor shall immediately carry out the necessary remedial work to restore corrosion resistance of the steel works at no cost to the Employer.

END OF SECTION