L&T CHIYODA LIMITED

Knowledge city, Ajwa Waghodia Crossing, VADODARA-391740

Industrial Training Project Report

(Date 14-05-2014 to 27-06-2014)

ON

DESIGN OF FOUNDATIONS FOR VERTICAL AND HORIZONTAL EQUIPMENT, DESIGN OF PIPE RACK AND ANALYSIS OF PORTAL FRAME

BY

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GUIDE

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ACKNOWLEDGEMENT

I am thankful to L&T CHIYODA LIMITED for providing Industrial Training for Six weeks. This short period has proved very impulsive in my life. It not only gave me exposure to Engineering Industry but also to the latest advancement in this very fast field. It has widened my vision as a Civil Engineer.

I am especially thankful to Mr. Anand Ghaisas (Head of Civil & Structural Department), Mr. Jigar Jadhav (Lead Engineer) for their guidance. Heartly thanks to Mr. Neerav Mehta, Mr. Anil Belani for supporting me time to time.

Special Regards to Ms. Elizabeth Praveen (AGM - HR) for giving me the opportunity to get trained at LTC.

Thanks,

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INTRODUCTION TO ORGANISATION

Larsen & Toubro-Chiyoda Limited (LTC)

L&T-CHIYODA LIMITED(LTC) is an Engineering consultancy organization formed by Larsen & Toubro Limited, leading and renowned engineering, manufacturing and construction company, and Chiyoda Corporation, Japan, company in Hydrocarbon and related fields since five decades.

Incorporated in 19th November 1994, LTC commenced operations In February 1995 and is serving national & international clients; both directly and through parent companies. LTC offers international grade engineering and project management services with integrated engineering concepts, supported by state-of-the-art computer hardware & software operating in a networking environment.

LTC, the youngest organization of its kind to get the ISO 9001 accrediting certification has established an independent identity amongst major clients and process know-how suppliers globally, through its indigenous and export engineering credentials. It has already upgraded its ISO certification to ISO 9001: 2000 and also achieved certifications for ISO 14001: 2004, ISO 27001: 2000, OHSAS 18001: 2007 and CMMI maturity level 5.

LTC has specialized for fast track EPC jobs of multiple complexities. The major industries in which LTC adds significant dimension includes Petroleum Refining, Petrochemicals, Chemicals, Fertilizers, Oil & Gas and CNG & LPG.

OVERVIEW OF PETROLEUM INDUSTRY

Petroleum being a Latin word is derived from Greek words Petra (rock) and Oleum (oil) or crude oil is a naturally occurring liquid found in formations of the earth, consisting of complex mixture of hydrocarbons.

Crude oil may also be found in semi- solid form mixed with sand, as in the Athabasca oil sands in Canada, where it might be referred to as crude bitumen.

Oil and natural gas are produced in by same geological process; anaerobic decay of organic matter, deep under the earth's surface.

As a consequence oil and natural gas are often found together. In common usage, deposits rich in oil ate called oil fields and deposits rich in natural gas are called natural gas fields.

In general organic sediments buried in depths of 1000 to 6000m (at a temperature of 60^{o}c to 150^{o}c) generates oil, while sediments buried deep at a high temperature generates natural gas.

Because both oil and natural gas are lighter than water, they tend to rise from their sources until they either seep to the surface or are trapped by a non permeable layer of rock. They can be extracted from the trap by drilling.

The oil industry is often divided into three categories:

1. Upstream
2. Midstream
3. Downstream

UPSTREAM SECTOR

It includes the searching for potential underground or underwater oil and gas fields, drilling of exploratory wells and subsequently operating the wells that recover and boring the crude oil and / or raw natural gas to the surface. The upstream sector is also known as the exploration and production (E&P) sector.

MIDSTREAM SECTOR

It does process, stores, markets and transports commodities such as crude oil, natural gas and natural gas liquids (NGL'S) such as ethane, propane and butane.

DOWNSTREAM SECTOR

The downstream sector includes oil refineries, petrochemical plants and petroleum product distribution companies. The downstream industry through numerous products such as gasoline (petrol), diesel, jet fuel, plastics, fertilizers, pesticides, natural gas, etc.

INTERFACE WITH OTHER DISCIPLINE

PROCESS	Process flow schemes, process and instrumentation diagram, process data sheets for equipment and instruments, hydraulics
LAYOUT AND PIPING	Plot plan and equipment layout development, coordination for 3D modeling, specifications for piping and valves , stress analysis for piping, design selection for pipe supports, underground piping, fire fighting
STATIC EQUIPMENT	Mechanical design and Engineering drawings of static equipment like vessels, vertical columns ; vendor related activities-specifications, requisitions, technical bid analysis, vendor document review
MACHINERY	Specifications and requisition for machinery items such as pumps, fans, compressors, technical bid analysis, and Vendor document review.
ELECTRICAL	Electrical system design, single line diagram, Cathode protection, layout related engineering for cable routing, lighting layout and design, PA system, fire alarm system, vendor related activities for electrical equipment, coordination for substation.
INSTRUMENATION AND CONTROL	Specifications and requisitions for in- line and field instruments for measurement, control systems-PLC and DCS, layout related engineering for cable routing, DCS related engineering and coordination for control building.

ENGINEERING ACTIVITIES UNDER CIVIL & STRUCTURAL DEPARTMENT

- Proposal Engineering
- Detail Engineering

Proposal Engineering includes

- Understanding bid requirements
- Recommendation on type of foundation
- Selection of material
- Technical bid analysis
- Estimation of quantity of civil, structural & architectural items, based on ITB and inputs from other engineering processes
- Budgetary cost estimation
- Preparation of civil tender

Detail engineering includes

- **General civil works**
    1. Site grading
    2. Fencing
    3. Roads, culverts and pavements
    4. Machine foundation
    5. Concrete pits and ponds
    6. Tank foundations and dyke walls
    7. Sewer system and UG composite
    8. Pipe sleepers
    9. Cable trench and duct bank
    10. Civil MTO

- **Structural civil works**
    1. Equipment support structures
    2. Column guide structure
    3. Operating stages
    4. Pipe racks

5. Pipe stanchions
6. Structural stanchions

- **Architectural works**
    1. Compressor house
    2. Sub-station building
    3. Control building
    4. Warehouse and workshop
    5. Non plant buildings

CLASSIFICATION OF EQUIPMENT

1. Static equipment
2. Dynamic equipment

Static equipment – Industrial equipment that does not contain moving parts or whose operational characteristics are essentially static in nature.

E.g. Heat Exchangers, electrical equipment such as transformers.

Dynamic equipment – Industrial equipment that contain moving parts or whose operational

Characteristics are essentially dynamic in nature.

E.g. Turbine generators, pumps, blowers, compressors etc.

GENERAL CONSIDERATIONS FOR STATIC FOUNDATION

The type and configuration of a foundation for equipment may be dependent on the following factors:-

1. Equipment base configurations such as legs, saddles, solid base, grillage or multiple support locations.
2. Anticipated loads such as the equipment static weight such as loads developed during erection, operational and maintenance.
3. Operational and process requirements such as accessibility, settlement constraints, temperature effects and drainage.
4. Erection and maintenance requirements.
5. Site conditions such as characteristics, topography, seismicity, climate and other environmental factors.
6. Economic factors such as capital cost, useful or anticipated life and replacement or repair cost.
7. Regulatory or building code provisions such as tied pile caps in seismic zones.
8. Constructional considerations.
9. Environmental requirements such as secondary containment or special concrete coating requirements.

TYPICAL FOUNDATIONS-

I. Vertical vessel

- ✓ For tall vertical vessels and stacks, the size of the foundation required to resist gravity loads and lateral wind and seismic forces. Hence the vessel is anchored to a pedestal.
- ✓ The pedestal is then supported o a large spread footing, mat or pile cap.
- ✓ Circular pedestal creates construction difficulties in forming. Square pedestals may need much more concrete then required. Hence to meet the optimism octagonal pedestals are preferred.

II. Horizontal vessel and heat exchanger foundation

- ✓ They are supported on pedestals that rest on spread footings, pile caps or drilled piers.
- ✓ Most commonly prismatic wall type pedestal is used.

TYPICAL DESIGN STEPS FOR FOUNDATION

- Identifying load and load combinations of it.
- Select a suitable type and geometry of the foundation according to the situation and need.
- Ensure a preliminary design and then do the required STABILITY CHECKS which are as follows:-
  - ❖ Soil Bearing Capacity Check
  - ❖ Sliding Check
  - ❖ Overturning check
  - ❖ Uplift Check
- Calculate the vertical stress and the bending moment diagram for the determination of thickness of members and reinforcement bars.
- After designing the foundation check for one way shear, check for two way shear and check for bearing stress.
- Then design the pedestal according to the IS 456:2007.

TYPE OF LOADING:

Loads acting on Main Pipe Rack viz. Dead Load, Live Load, Pipe Load, Equipment Load, Wind Load and Earthquake Load are considered as below:

1. Dead Load "DL":- Self Weight of members is automatically calculated by STAAD/Pro according to density of material. Electrical and instrument cable loads including the tray/ duct supporting system loads as supplied by EL/ IN department are considered.
Weight of platforms including grating and secondary joists is considered as
1.0 KN/m2.

2. Live Load "LL":- Live Load on Service platform/ platform for valve operation/ access way shall be taken as 5 kN/m^2. Live Load on operating platform shall be taken as 5 kN/m^2.
Live Load on staircase of service platform shall be taken as 2.5 kN/m^2

3. Equipment Load "E":- Equipment loads are classified in following three classes based on their conditions.

1. Equipment loads for Erection / Empty "E(E)"
This includes weight of equipment during erection / empty including platforms,
Insulation and piping attached to the equipment and exclude weight of internals,
Fluids and solids within the equipment

2. Equipment loads for Operation "E(O)"
Includes equipment load for erection plus weight of internals, fluids and solids within the equipment.

3. Equipment loads for Testing "E(T)
Includes equipment load for erection plus weight of hydro test water within the
Equipment.

4. Piping Load "P":- Piping loads are classified in following three class based on their conditions.

1. Piping loads for Erection / Empty "P(E)"
Includes self wt. of pipe, insulation, valves etc.

2. Piping loads for Operation "P(O)"
Includes Piping erection loads plus weight of internal fluid

<u>3. Piping loads for Test “P(T)”</u>
Includes Piping erection loads plus weight of water within piping
The above loads shall be considered as per Inputs from Piping department.

5. Wind Load “WL”

Wind load shall be as per IS: 875 (Part-3).

Basic Wind Speed	39 m/ sec
Risk Coefficient k1	1.0 for permanent structures and 0.76 for temporary facilities.
Terrain, Height and Structure Size Factor k2	Factor for relevant class of the structure with Category-2 terrains. (As per Table 2 of IS:875 Part-3)
Topography Factor k3	1.0

Design Wind speed shall be worked out based on basic wind speed and k1, k2, k3, using IS: 875-Part3.

Design wind pressure (Pd) shall be worked out based on design wind speed using IS: 875 - Part-3.

Wind forces on structural elements shall be calculated using design wind pressure Multiplied by element frontal area normal to wind direction multiplied by force coefficient as per IS: 875. Appropriate shielding factor shall be considered as per IS: 875.

For Pipe rack, transverse wind loading shall be calculated depending on the width of the Pipe rack as per the following table.

Width of Pipe Rack	Wind force at each tier level (kN)
Upto 4.0 m	1.25 x p x s
Above 4.0 m upto 6.0 m	1.5 x p x s
Above 6.0 m upto 10.0 m	2.0 x p x s

Where p = Horizontal wind pressure as per IS: 875 (kN/m2)
s = spacing of portals (m)

Above mentioned wind force formulae includes the wind force on structure and pipe.
Wind load on cable trays/ ducts shall be worked out separately.

For flare header or any other line supported on extended leg of pipe rack the wind force shall be calculated separately.

6. Seismic Force “EQ”

Seismic loads shall be as per IS: 1893, Part I and IV.
Seismic force shall be as per ITB Document 6249-A-119-007-R2.
Increase in permissible stresses shall be as per IS: 1893.

7. Thermal Friction Force “TF”

Thermal force is defined as the force occurring due to thermal expansion or contraction of the vessel or piping on the supporting structure or pipe rack.

The sliding friction forces shall be calculated in accordance with the actual conditions. The friction coefficients to be used in determining lateral loads due to sliding shall be as follows, unless otherwise specified:

Steel to concrete	0.5
Concrete to soil	0.414
Steel to steel	0.3
PTFE to PTFE	0.1

Where the pipes are of similar diameter and service conditions, the friction force at each tier on every portal both in longitudinal and transverse directions shall be considered as follows.

- 1 to 3 pipes : 30% of the design vertical load
- More than 3 pipes : 10% of the design vertical load

Longitudinal friction force shall be considered as uniformly distributed over the entire span of the beam at each tier.

Transverse friction force shall be considered as a concentrated load at each tier level.

Friction force on T supports and trestles shall be taken as 30 % and 10 % of vertical load in longitudinal and transverse direction respectively acting simultaneously.

For two-phase fluid flow/transfer lines the frictional force shall be minimum 50% of the weight of pipe including contents and insulation, acting simultaneously in
Transverse and longitudinal directions.

Friction Force shall be considered for design of Framing beams & Columns however the same shall not be considered for design of foundations.

DESIGN OF VERTICAL EQUIPMENT FOUNDATION

1) GENERAL

1.1- Specification for design

The design calculations are in accordance with design philosophy for vertical equipment foundation.

1.2- Codes and References used

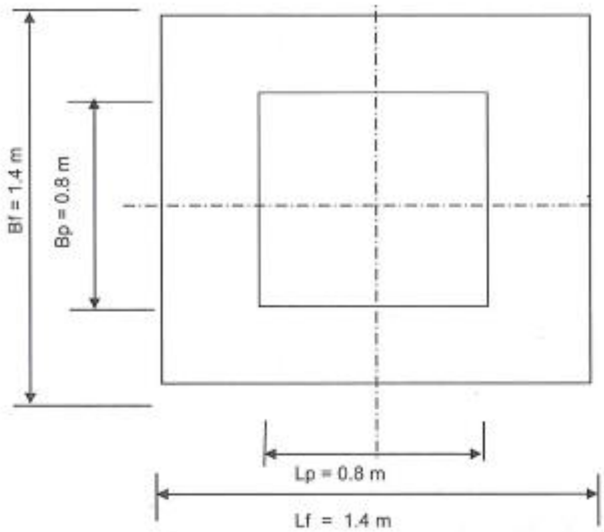
IS 456:2000 – code of practice for plain and reinforced concrete

ACI 351.2-94: foundations for static equipment

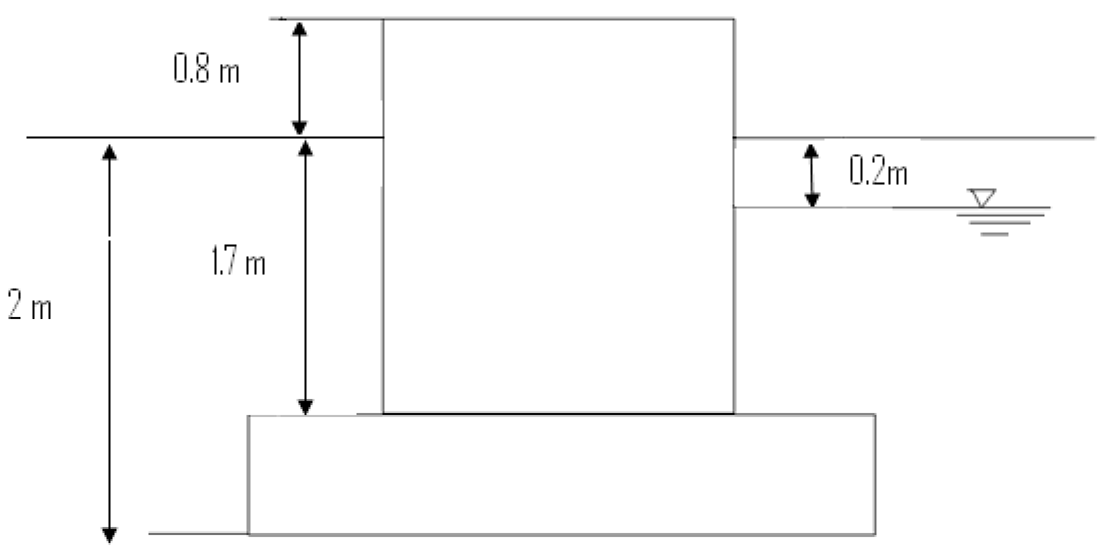
1.3- Design Parameters

- Structural concrete
  - ✓ Unit weight (density) γ_c = 25 KN/m^3
  - ✓ Concrete grade (f_{ck}) = 25 MPa
- Reinforcing steel grade (f_y) = 500 MPa
- Footing side concrete cover E-W dir. = 50mm
- Footing side concrete cover N-S dir. = 50mm
- Footing top concrete cover = 75mm
- Footing bottom concrete cover= 75mm
- Soil parameters
  - ✓ Net soil bearing capacity = 500 KN/m^2
  - ✓ unit weight = 19 kN/m^3
- Depth of foundation = 2m below HPP

3) GEOMETRY OF FOUNDATION



PLAN



3. LOADING DATA

- Fabricated weight = 6.5KN
- Operating weight = 10KN
- Test weight = 11 kN
- Max shear at base
  - ✓ Wind load = 0.8 KN
  - ✓ Seismic load = 3.4 KN
- Max moment at base
  - ✓ Wind = 1.5 KNm
  - ✓ Seismic = 7.1 KNm

Area of footing (Af) = 1.4*1.4 = 1.96m^2

Weight of pedestal (w_p) = 2.5*0.8*0.8*25= 40 KN

Weight of soil (w_s) = ((1.4*1.4)-(0.8*0.8))*1.7*19 =42.64 KN

Weight of footing (w_f) = 0.3*1.4*1.4*25 = 14.7 KN

Buoyant force (Vf)= (2-0.2)*1.4*1.4*9.8 =34.57 kN

Total weight of foundation (W_{fd}) = w_p+ w_s+ w_f - v_f

= 36.8 +62.7 +10.5 -34.57

= **62.77KN**

CAUSED BY		LATERAL FORCE (KN)	OVERTURNING MOMENT(KNM)
WIND LOAD	OPERATING	Hw_1= 0.8	Mw_1= 1.5 + (0.8*2.8) = 3.74
SEISMIC FORCES	OPERATING	He= 3.4	Me = 7.1 + (3.4*2.8) = 16.62

LOAD COMBINATIONS	PERM. STRESS FACTOR
LC1 -ERECTION LOAD	1
LC2- ERECTION WITH WIND LOAD	1.25
LC3 -OPERATING LOAD	1
LC4- OPERATING WITH WIND LOAD	1.25
LC5 -OPERATING WITH SEISMIC LOAD	1.25
LC6 -HYDROSTATIC TEST WEIGHT	1
LC7- HYDROSTATIC TEST WEIGHT WITH 25 %WIND LOAD	1.25

CONDITION	Wfd (kN)	Wx(kN)	Px (kN)	Mx(kN m)	My(kN m)
empty	62.77	6.5	69.27		
empty + wind	62.77	6.5	69.27	3.74	3.74
operating	62.77	10	72.77		
operating + wind	62.77	10	72.77	3.74	3.74
operating + seismic	62.77	10	72.77	16.62	16.62
hydro test	62.77	11	73.77		
test + wind	62.77	11	73.77	0.935	0.935

2) STABILITY ANALYSIS

1. Check for soil bearing pressure

For LC1,LC4, LC7,LC2X,LC3X,LC5X,LC6X,LC8X

Smax/min =(Wfd+W)/Af*(1±6*ex/A5)

For LC2Y , LC5Y, LC6Y, LC8Y

Smax/min =(Wfd+W)/Af*(1±6*ey/B1)

	FORCE			ECCENTRIC DISTANCE				SOIL PRESSURE		
case	Wfd+W	Mx	My	ex	ey	ex/L	ey/B	Smax	Smin	ALLOW
LC1	69.27	0	0	0	0	0	0	3.99	3.99	538
LC2x	69.27	0	3.74	0.054	0	0.039	0	4.91	3.07	663
LC2y	69.27	3.74	0	0	0.054	0	0.04	3.99	3.99	663
LC4	72.77	0	0	0	0	0	0	4.19	4.19	538
LC5x	72.77	0	3.74	0.051	0	0.037	0	5.12	3.27	663
LC5y	72.77	3.74	0	0	0.051	0	0.04	4.19	4.19	663
LC6x	72.77	0	16.62	0.228	0	0.163	0	8.29	0.09	663
LC6y	72.77	16.62	0	0	0.228	0	0.16	4.19	4.19	663
LC7	73.77	0	0	0	0	0	0	4.25	4.25	538
LC8x	73.77	0	0.935	0.013	0	0.009	0	4.48	4.02	663
LC8y	73.77	0.935	0	0	0.013	0	0.01	4.25	4.25	663

2. **<u>Check for overturning:</u>**

Its defined as the ratio of resisting moments to driving moments. And this ratio should be less than 1.5 for design to be safe. It can generalized to the following formula.

FS=L/(2*e)

WHERE e = ECCENTRICITY DISTANCE (m) = M / (Wfd+W)

M = OVERTURNING MOMENT (kN m)
Wfd = FOUNDATION WEIGHT (kN)
W = EQUIPMENT WEIGHT (kN)
L = FOOTING DIMENSION (m)

CASE	M	Wfd+W	e	L	F.S.	MIN F.S.	CHECK
LC2X	3.74	69.27	0.054	1.4	12.96	1.5	o.k.
LC2Y	3.74	69.27	0.054	1.4	12.96	1.5	o.k.
LC5X	3.74	72.77	0.051	1.4	13.62	1.5	o.k.
LC5Y	3.74	72.77	0.051	1.4	13.62	1.5	o.k.
LC6X	16.62	72.77	0.228	1.4	3.06	1.5	o.k.
LC6Y	16.62	72.77	0.218	1.4	3.21	1.5	o.k.

3) <u>Check for Sliding</u>

Its defined as the ratio of the friction force(ie the resisting force in horizontal direction) to the net force in horizontal direction. This ratio should be greater than 1.5 for design to be safe.

F.S. = (Wfd+W) x μ / H

WHERE Wfd = FOUNDATION WEIGHT (kN)
W = EQUIPMENT WEIGHT (kN)
H = LATERAL FORCE (kN)(DUE TO WIND OR SEISMIC)
μ2 = FRICTION COEFFICIENT (SOIL TO CONCRETE)=0.414

CASE	Wfd+W	H	F.S.	MIN F.S.	CHECK
LC2X	69.27	0.8	35.85	1.5	o.k.
LC2Y	69.27	0.8	35.85	1.5	o.k.
LC5X	72.77	3.4	8.86	1.5	o.k.
LC5Y	72.77	3.4	8.86	1.5	o.k.
LC6X	72.77	3.4	8.86	1.5	o.k.
LC6Y	72.77	3.4	8.86	1.5	o.k.

DESIGN OF VERTICAL EQUIPMENT FOUNDATION - OCTAGONAL FOOTING

1) GENERAL

1.1-Specification for design

The design calculations are in accordance with design philosophy for vertical equipment foundation.

1.2- Codes and References used

IS 456:2000 – code of practice for plain and reinforced concrete
ACI 351.2-94: Foundations for static equipment.

1.3- Design Parameters

- Structural concrete
  - ✓ Unit weight (density) γ_c = 24 KN/m^3
  - ✓ Concrete grade (f_{ck}) = 20 MPa
- Reinforcing steel grade (f_y) =500 MPa
- Covers for main bars of footing = 50mm
- Covers for main bars of pedestal = 45mm
- Soil parameters
  - ✓ Net soil bearing capacity = 180 KN/m^2
- Depth of foundation = 3m below HPP

2) LOADING DATA

- Fabricated weight (w_e) = 332.70KN
- Operating weight (w_o) = 816.90KN
- Test weight (w_t)= 938.90
- Vertical seismic load (operating conditions) = 107.50 KN
- Max shear at base
  - ✓ Wind load = 27.20 KN
  - ✓ Seismic load = 161.20 KN
- Max moment at base

- ✓ Wind = 152.60 KNm
- ✓ Seismic = 1407.20 KNm

Area of footing (Af) = .8284*6*6 = 29.8224m^2

Weight of pedestal (w_p) = .8284*3*3*2.8*25 = 521.892 KN

Weight of soil (w_s) = (29.8224-.8284*3*3)*2.5*19 = 1062.43 KN

Weight of footing (w_f) = 29.8224*0.5*25 = 372.78 KN

Total weight of foundation (W_{fd}) = w_p+ w_s+ w_f

= 521.892+1062.43+372.48

= **1957.102 KN**

CAUSED BY		LATERAL FORCE (KN)	OVERTURNING MOMENT(KNM)
WIND LOAD	OPERATING	Hw_1= 27.20	Mw_1= 152.60 + (27.20*3.3) = 242.36
SEISMIC FORCES	OPERATING	He= 161.20	Me = 1407.20 + (161.20*3.3) = 1939.16

LOAD COMBINATIONS	**PERM. STRESS FACTOR**
LC1 -ERECTION LOAD	**1**
LC2- ERECTION WITH WIND LOAD	**1.25**
LC3 -OPERATING LOAD	**1**
LC4- OPERATING WITH WIND LOAD	**1.25**
LC5 -OPERATING WITH SEISMIC LOAD	**1.25**
LC6 -HYDROSTATIC TEST WEIGHT	**1**
LC7- HYDROSTATIC TEST WEIGHT WITH 25 %WIND LOAD	**1.25**

3) ECCENTRICITY & INTENSITY OF SOIL BEARING

LC5 – OPERATING + SEISMIC

- ✓ Weight of foundation (W_{fd}) = 1957.102 KN
- ✓ Equipment operating weight (w_o) = 816.90 KN
- ✓ Total load at the base of footing (p_z)= 2774.002 KN
- ✓ Moment at base due to horizontal force (Ml_e)= 1939.16 KNm.
  - Eccentricity = moment /load

    = 1939.16/2774.002

    = 0.7
  - e/d = 0.7/ 6

    = 0.117

FROM GRAPH :

Ln= 1.75 Ln’ = 2 – Ln = 2-1.75 = .25

Lm =1.9 Lm’ =2 – Lm =2-1.9 = 0.1

LOAD CASE	LOAD	M	E	e/d	Lm	Lm'	Ln	Ln'	Smax	Smin	Smax	Smin
	P								n		m	
LC5	2774.0	1939.16	0.699	0.116	1.9	0.1	1.75	0.25	162.78	23.25	176.73	9.30

Permissible soil bearing capacity (Sz) = (180*1.25)+(18*3.3)

= 284.4 KN/m^2

Hence Sm, Sm’, Sn, Sn’ are < Sz ------- > the design is safe

4) CHECK FOR STABILITY:-

4.1- Check for overturning

Factor of safety = 0.5/(e/d)

=0.5/0.117

= 4.27 > 2 (minimum factor of safety)

SAFETY AGAINST OVERTURNING

4.2- Check for sliding

Factor of safety= (Wfd + Wo)*μ/ He

= (1957.102+816.90)*0.414/ 161.20

= 7.12 >> 1.5 (minimum factor of safety)

SAFETY AGAINST SLIDING

DESIGN OF OCTAGONAL FOOTING -

Taking the most critical case as:

LC5 → Operating + seismic in m - m' axis

From the analysis $S_{max} = 176.731\ kN/m^2$

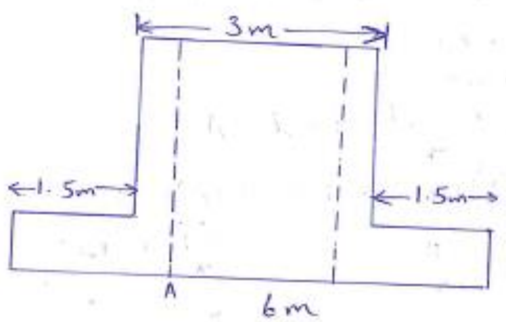
$S_{min} = 9.30174\ kN/m^2$

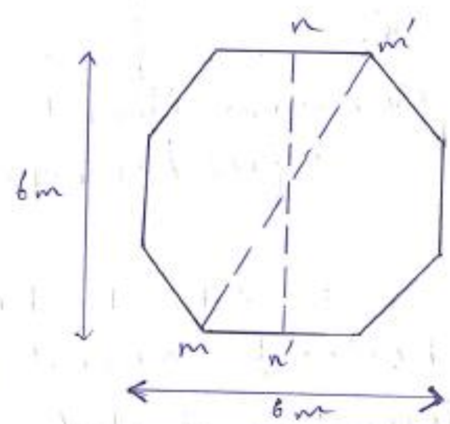
Thickness of footing = 500 mm

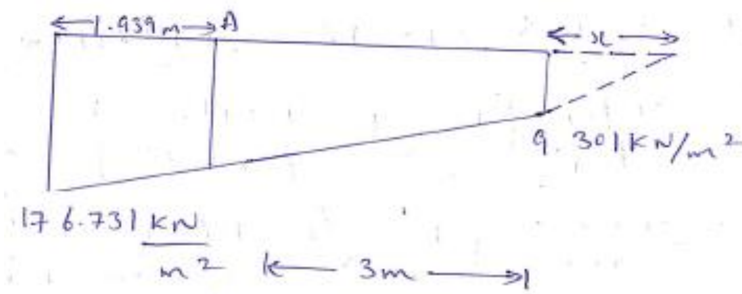
Cantilever length = 1.5 m = 1500 mm

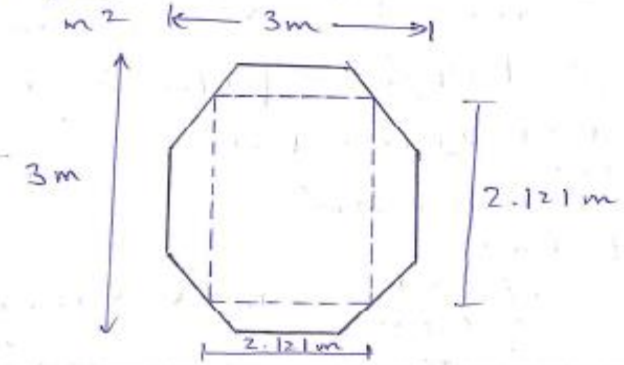
Length of footing = 6000 mm

Breadth of footing = 6000 mm





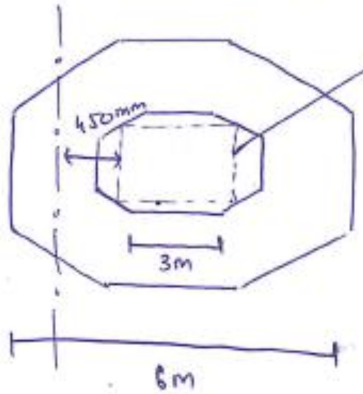




Inscribed square as per cl: 34.2 of IS: 456 2000 for purpose of stress computation

Check for One Way Shear

At a distance 'd' from face of equivalent square



As per Cl. 34.2 → IS : 456 : 2000

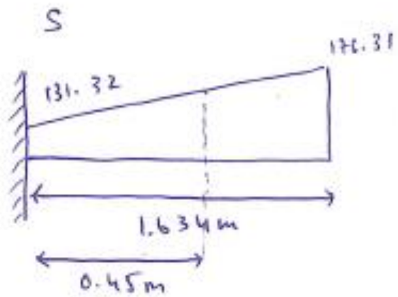
$A = 0.8284 * 3^2$

$= 7.456 \ m^2$

Size of equivalent square

$= \sqrt{7.456}$

$= 2.73 m$



SBC at 1.634m

$\Rightarrow \frac{176.73}{S} = \frac{6.33}{4.69}$

$S = 131.132 kN/m$

SBC @ critical section

$\frac{176.731}{S} = \frac{6.33}{5.14} \Rightarrow S = 143.68 \ kN/m$

Shear force $= 143.68 \times 1.184 + \frac{1}{2} \times 1.184 \ (176.731 - 143.68)$

$= 189.68 \ kN$

$\tau_v = \frac{V_u}{bd} = \frac{189.68 \times 10^3}{1000 \times 450}$

$= 0.321 \ N/mm^2$

from IS : 456 : 2000 → Table 19

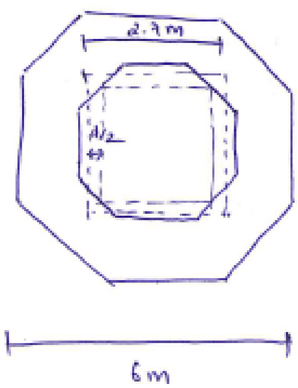
τ_c for $(0.33\%) = 0.37 \ N/mm^2$

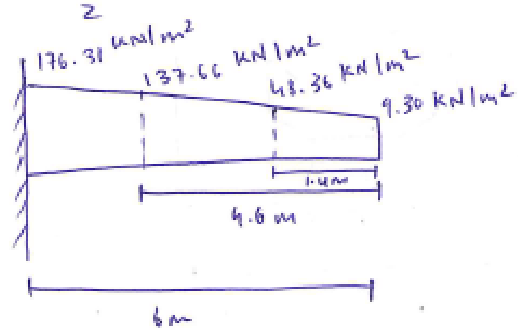
↳ okay

CHECK FOR TWO WAY SHEAR

at d/2 from equivalent square

Hence $\frac{d}{2} = \frac{450}{2} = 225\,mm$





at 4.6m, $\frac{176.73}{2} = \frac{6.333}{4.933} \Rightarrow 137.66\,kN/m$

at 1.4m, $\frac{176.73}{x} = \frac{6.333}{1.533} \Rightarrow 48.36\,kN/m^2$

$b = 3200 \times 4 = 12800\,mm$

$d = 225\,mm$

$V_u = \left[9.301 \times 6 + 3 \times (176.731 - 9.301)\right] - \left[48.36 \times 3.2 + \frac{1}{2} \times 3.2\,(137.66 - 48.36)\right]$

$= -297.632 + 558.096\,kN$

$= 260.64\,kN$

→ $\tau_v = \frac{V_u}{b.d} = \frac{260.64 \times 10^3}{12800 \times 225} = 0.0813\,N/mm^2$

→ For M25, Table 21, IS 456 : 2000

$\tau_c = 0.37\,N/mm^2$

$k_s = 0.5 + \beta_c$

$= 0.5 + 1 = 1.5 < 1$

$= \underline{\underline{1}}$

$k\tau_c > \tau_c \rightarrow$ okay

CHECK FOR BEARING STRESS

Bearing Pr on loaded area $= \dfrac{\text{load}}{\text{Area}}$

$= \dfrac{558.096 \times 10^3}{0.8284 \times 6000 \times 6000}$

$= 0.0187\ N/mm^2$

Permissible bearing stress $= 0.45\ f_{ck} \sqrt{\dfrac{A_1}{A_2}}$

$= 0.45 \times 25 \sqrt{\dfrac{0.8284 \times 6^2}{0.8284 \times 3^2}}$

$= 22.5\ N/mm^2 > 0.0187\ N/mm$

Hence safe.

REINFORCEMENT

Weight of soil $= 2.5 \times 19 = 47.5\ KN/m^2$

Consider unit width $\Rightarrow w = 47.5\ KN/m$

Moment $= 47.5 \times 0.75 \times 1.5 = \underline{\underline{53.43\ KNm}}$

$p_t = \dfrac{50 \times 25}{500} \left\{ 1 - \sqrt{1 - \dfrac{4.6 \times 53.43 \times 10^6}{25 \times 1000 \times 450^2}} \right\}$

$= 0.061\% < p_{t\,min}$

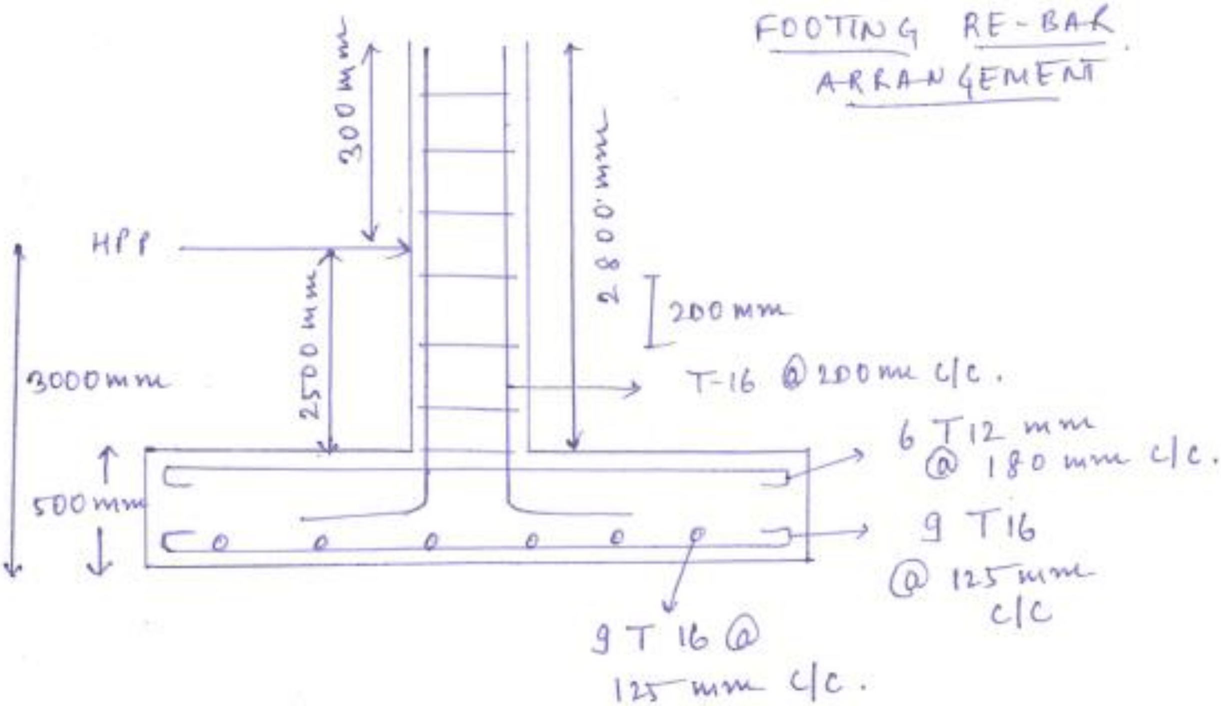
Hence $p_{t\,req} = 0.12\%$

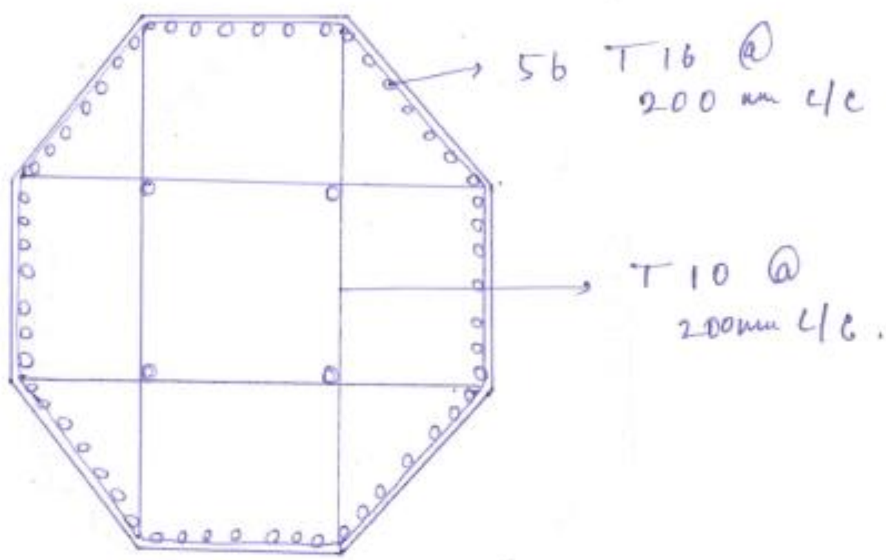
$A_{st\,req} = \dfrac{0.12}{100} \times 1000 \times 450 = 540\ mm^2$

No of bars $= \dfrac{540}{\frac{\pi}{4} * 12^2} = 4.77 \Rightarrow 6$ bars

$\Rightarrow$ 6T-12mm @ 180mm c/c

FOOTING RE-BAR ARRANGEMENT





REBAR ARRANGEMENT OF PEDESTAL

DESIGN OF HORIZONTAL VESSEL AND HEAT EXCHANGER FOUNDATION AND PEDASTAL (COMBINED FOOTING)

1.GENERAL

1.1 Specification for design

Design calculations are in accordance with design philosophy of horizontal vessel and heat exchanger foundation

1.2 Codes and references used

IS: 456-2000: code of practice for plain and reinforced concrete; SP - 16 Charts; IS : 875-(part3)1987, IS:1893.

1.3 Design parameters

- Structural concrete

  Unit weight density γc = 25 kN/m^3

  Concrete grade (fck) = 25MPa

-Reinforcing steel

  Grade fy = 500MPa

-Cover and protective coating material

  Cover for main bars of footing = 50 mm

  Cover for main bars of pedestal = 45mm

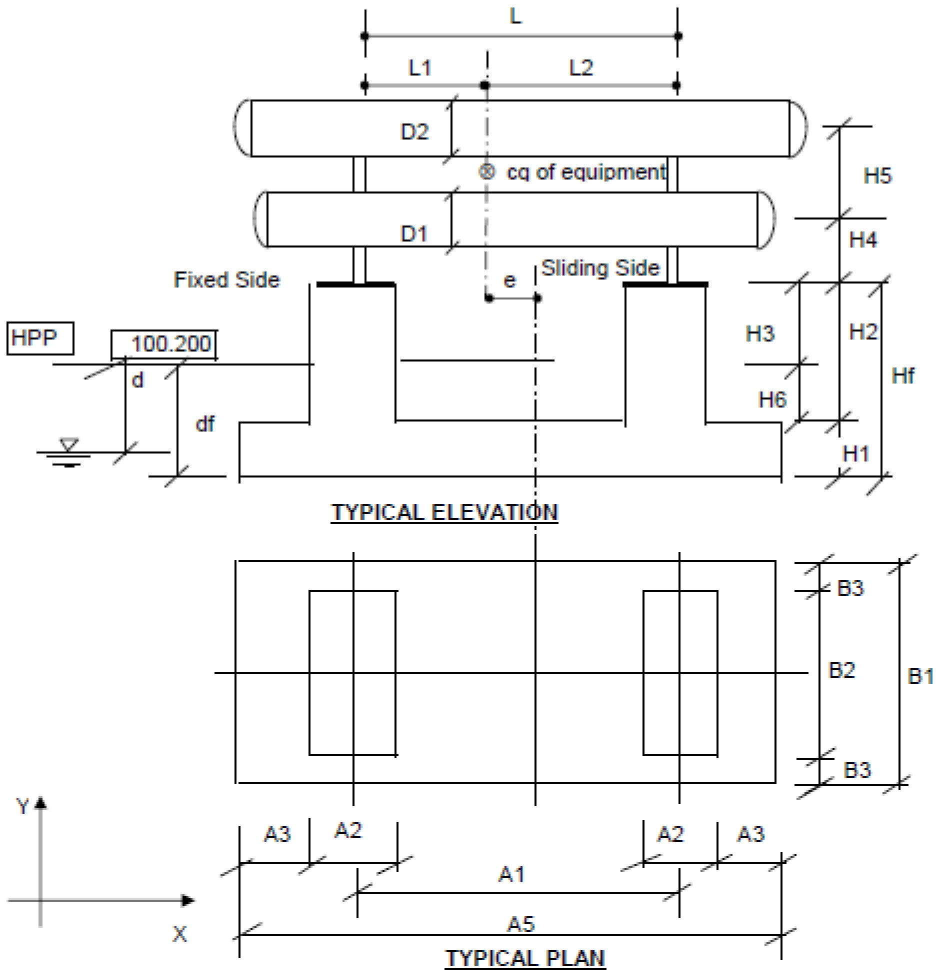
-Foundation parameters

  Net bearing capacity = 500 kN/m^2
  Gross bearing capacity = 561 kN/m^2
  Depth of foundation from HPP (Df) = 3.2m
  Unit weight of soil γs = 19 kn/m^3

2.FOUNDATION GEOMETRY

UNIT : (m)

Legend	Value	Legend	Value	Legend	Value	Legend	Value	Legend	Value
L	**4.000**	Hf=H1+H2	4.600	H5	**0.000**	A1	4.000	B1	2.800
D1	**1.282**	H1	**0.500**	H6=df-H1	2.700	A2	**0.600**	B2	**1.200**
D2	**0.000**	H2=H3+H6	4.100	df	**3.200**	A3	**0.800**	B3	**0.800**
L1	**2.953**	H3	**1.400**	dw	0.20	A5	6.200		
L2	1.047	H4	**0.900**						



TYPICAL ELEVATION

TYPICAL PLAN

3 LOADING DATA

- **Empty weight (We)** = 232.10 kN
- **Operating weight (Wo)=** 304.60 kN; vertical seismic load = 20.1kN

  Wo = 304.60 – (0.3 * 20.1)= 298.57 kN

- **Hydrostatic test weight (Wh)** = 325.40 kN
- **Tube bundle weight (Wt)** = 138.40 kN
- **Wind load**

  Max shear at base (Hwl)= 7.40 kN

  Moment at base = 6.7KNm

  Since pedestal is of considerable height above HPP wind load on pedestal has to be considered as per IS:875 (PART3)

  Design wind speed Vz = K1*K2*K3*Vb

  = 1*1*1*39

  = 39 m/s

  Design wind pressure Pz = 0.6 *Vz^2

  = 912.60 N/m^2

  Total wind force =F= Cf*A*Pz

  Hwp1= total wind force along X= 2*B2*H3*Cf*Pz= 6.13 kN

  Hwp2= total wind force along Y= 2*A2*H3*Cf*Pz=3.07 kN

  Hwp=max(Hwp1, Hwp2)= 6.13 kN

  Total wind load Hw =6.13+7.40= 13.53 Kn

- **Thermal force**

  Horizontal load due to Thermal expansion of heat exchanges and horizontal vessels shall computed on top of saddle supports under Equipment operating (Eo) case as follows;

  Htf = Max[(L1/L)*Wo*µ or (L2/L)*Wo*µ]

  where,
  W_ = Operating Weight of Equipment
  µ = Coefficient of friction= 0.3 (Steel to Steel), 0.1 (PTFE to PTFE) & 0.414 (Concrete to Soil)
  L1, L2 = Location of C.G. of equipment fix side & sliding side
  L = C/C distance of saddle
  Hte = (0.5 x α x ΔT x L) x (3 x E x I / $H2^3$)
  where,
  α = Coefficient of linear expansion = 1 x10(-5) per _C
  ΔT = Temperature difference
  L = Saddle to Saddle distance
  E = Young's modulus of Elasticity (Steel) = 2 x10 5 MPa.
  I = Moment of Inertia of Pedestal
  H2 = Height of Pedestal above top of foundation.

  Total Thermal force is min. of Thermal friction force (Htf) & Thermal expansion (Hte) force

  Htf= 44.79kN

  Hte = 47.01 kN

  Hence thermal force Ht= 44.79 kN

- **Foundation weight(Wfd)**

  Weight of footing (Wf)= A5*B1*H1* γc = 217.00 kN

  Weight of pedestal (Wp) = 2* A2*B2*H2* γc = 147 .60 kN

  Weight of soil on footing (Ws) = (A5*B1 -2*A2*B2)*H6* γs = 816.70 Kn

  Buoyant force (Vf) = Af* (df –dw)* 9.8= 510.38 kN

  Wfd= Wf +Ws+ Wp –Vf = 670.91 kN

- **Seismic load**

  Shear at base:-30.4KN
  Moment at base:- 27.3KNm

Earthquake load (Shear force and moment due to earthquake at top of pedestal) on Equipment

are supplied by Equipment Department.

- Seismic forces on pedestals are calculated as a rigid body consideration using
  Simplified Method [Equivalent Static Lateral Force Method] as specified in Clause
  10.3.1 of IS 1893 (Part 4): 2005.
  • Category – 2 shall be adopted as per Table 5 of IS 1893 (Part 4): 2005 for horizontal
  vessel / heat exchanger foundation.
  • Damping for concrete structure shall be considered 5% as per table 7 of IS 1893,
  Part IV.
  • Importance factor, I shall be taken as 1.75 as per Table 2 of IS 1893 (Part 4): 2005
  for Category - 2.
  • Response reduction factor R, shall be taken as 3 considering Ordinary RC moment
  resisting frame (OMRF) as given in Table 3 of IS 1893 (Part 4): 2005.

Total Earthquake Load acting in specified direction
V = Ah x W
where,
W = Seismic weight of member
Ah = Seismic Co-efficient
= (Z/2) x (Sa/ g) x (I/ R)
= (0.16/2) x (2.5) x (1.75/ 3) = 0.117
Sa/g = 2.5 as per Fig-2 Response spectra for rock and soil sites for 5% damping IS 1893 (Part-1).

kp = SEISMIC FACTOR FOR PEDESTAL = **0.117**
Kf = SEISMIC FACTOR FOR FOOTING = **0**
ks = SEISMIC FACTOR FOR SOIL ON FOOTING = **0**

He = Hel + Hep +Hef +Hes
= (Hel) + (kp x Wp) + (kf x Wf) + (ks x Wso)
= 47.62 KN

4. COMPUTATION OF OVERTURNING MOMENT

Mw	Mwl + Hwl x Hf = 68.95 kN m
Me	Mel +(Hel x Hf)+(Hep x (H1 + H2/2)) +(Hef x H1/2)+(Hes x (H1 + H6/2)) = 211.05 kN m
Mbl	Hbl x (Hf + H4) = 654.63 kN m
Mbu	Hbu x (Hf+H4+H5) = 211.53 kN m
Mb	MAX (Mbl, Mbu) = 654.63 kN m
Mt	Ht*Hf = 206.01 kNm
Mse	We*eccentricity =221.19 kN
Mso	Wo*eccentricity=284.54 kN
Msh	Wh*eccentricity=310.11 kN

Where,

Mw- CAUSED BY WIND LOAD
Me- CAUSED BY SEISMIC LOAD
Mb- CAUSED BY TUBE BUNDLE PULLING FORCE Mb
Mt- CAUSED BY THERMAL LOAD Mt 206.01 (Only for Pedestal Design)
Mse- CAUSED BY ECCENTRIC POSITION OF C.G.(EMPTY)
Mso- CAUSED BY ECCENTRIC POSITION OF C.G.(OPER)
Msh- CAUSED BY ECCENTRIC POSITION OF C.G.(HYD. TEST)

6 LOAD COMBINATIONS

Permissible soil bearing pressure referring IS:1904 CL 15.1.7 and IS : 1893 table 1

LOAD COMBINATIONS	**PERM. STRESS FACTOR**
LC1 -ERECTION LOAD	**1.00**
LC2Y- ERECTION WITH WIND LOAD (ALONG Y-DIRECTION)	**1.25**
LC2X -ERECTION WITH WIND LOAD (ALONG X-DIRECTION)	**1.25**
LC3X -MAINTENANCE COND. WITH TUBE BUNDLE PULLING FORCE (ALONG X-DIRECTION)	**1.25**
LC4 -OPERATING LOAD	**1.00**
LC5Y- OPERATING WITH WIND LOAD (ALONG Y-DIRECTION)	**1.25**
LC5X -OPERATING WITH WIND LOAD (ALONG X-DIRECTION)	**1.25**
LC6Y -OPERATING WITH SEISMIC LOAD (ALONG Y-DIRECTION)	**1.25**
LC6X -OPERATING WITH SEISMIC LOAD (ALONG X-DIRECTION)	**1.25**
LC7 -HYDROSTATIC TEST WEIGHT	**1.00**
LC8X- HYDROSTATIC TEST WEIGHT WITH 25 %WIND LOAD (ALONG X -DIRECTION)	**1.25**
LC8Y -HYDROSTATIC TEST WEIGHT WITH 25 %WIND LOAD (ALONG Y-DIRECTION)	**1.25**

CASE	CONDITION	Wfd (kN)	Wx(kN)	Px(kN)	Mx(kN m)	My(kN m)	Mse(kN m)
LC1	empty	670.91	232.1	903.01			221.19
LC2	empty + wind	670.91	232.1	903.01	68.95	68.95	221.19
LC3	empty + bundle	670.91	232.1	903.01	654.63	654.63	221.19
LC4	operating	670.91	298.57	969.48			284.54
LC5	operating + wind	670.91	298.57	969.48	68.95	68.95	284.54
LC6	operating + seismic	670.91	298.57	969.48	211.05	211.05	284.54
LC7	hydrotest	670.91	325.4	996.31			310.11
LC8	test + wind	670.91	325.4	996.31	17.24	17.24	310.11

STABILITY ANALYSIS

1. **CHECK ON SOIL BEARING PRESSURE**

   For LC1,LC4, LC7,LC2X,LC3X,LC5X,LC6X,LC8X

   $S_{max/min}$ =(Wfd+W)/Af*(1±6*ex/A5)

   For LC2Y , LC5Y, LC6Y, LC8Y

   $S_{max/min}$ =(Wfd+W)/Af*(1±6*ey/B1)

	FORCE			ECCENTRIC DISTANCE				SOIL PRESSURE		
case	Wfd+W	Mx	My	ex	ey	ex/A5	ey/B1	Smax	Smin	ALLOW
LC1	903.01	0	221.19	0.245	0	0.040	0	64.35	39.69	560.8
LC2x	903.01	0	68.95	0.076	0	0.012	0	55.86	48.17	685.8
LC2y	903.01	68.95	221.19	0.245	0.076	0.040	0.027	60.53	43.51	685.8
LC3x	903.01	0	875.82	0.970	0	0.156	0	100.84	3.19	685.8
LC4	969.48	0	284.54	0.293	0	0.047	0	71.71	39.98	560.8
LC5x	969.48	0	68.95	0.071	0	0.011	0	59.69	52.00	685.8
LC5y	969.48	68.95	284.54	0.293	0.071	0.047	0.025	64.36	47.33	685.8
LC6x	969.48	0	211.05	0.218	0.000	0.035	0	67.61	44.08	685.8
LC6y	969.48	211.05	284.54	0.293	0.218	0.047	0.078	81.90	29.79	685.8
LC7	996.31	0	310.11	0.311	0.000	0.050	0	74.68	40.10	560.8
LC8x	996.31		17.24	0.017	0.000	0.003	0	58.35	56.43	685.8
LC8y	996.31	17.24	310.11	0.311	0.017	0.050	0.006	74.68	40.10	685.8

2. CHECK FOR OVERTURNING

FS=L/(2*e)

WHERE e = ECCENTRICITY DISTANCE (m) = M / (Wfd+W)
M = OVERTURNING MOMENT (kN m)
Wfd = FOUNDATION WEIGHT (kN)
W = EQUIPMENT WEIGHT (kN)
L = FOOTING DIMENSION (A5,B1) (m)

CASE	M	Wfd+W	e	L	F.S.	MIN F.S.	CHECK
LC2X	68.95	903.01	0.076	6.2	40.60	1.5	o.k.
LC2Y	68.95	903.01	0.076	2.8	18.34	1.5	o.k.
LC3X	654.63	903.01	0.725	6.2	4.28	2	o.k.
LC5X	68.95	969.48	0.071	6.2	43.59	1.5	o.k.
LC5Y	68.95	969.48	0.071	2.8	19.68	1.5	o.k.
LC6X	211.05	969.48	0.218	6.2	14.24	1.5	o.k.
LC6Y	211.05	969.48	0.218	2.8	6.43	1.5	o.k.

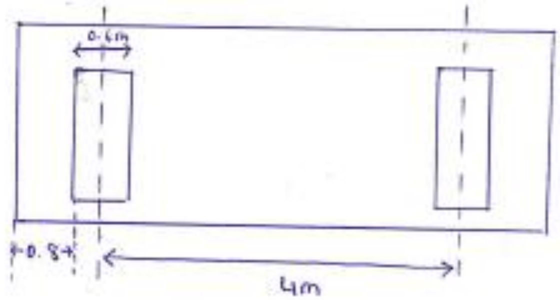
3. CHECK AGAINST SLIDING

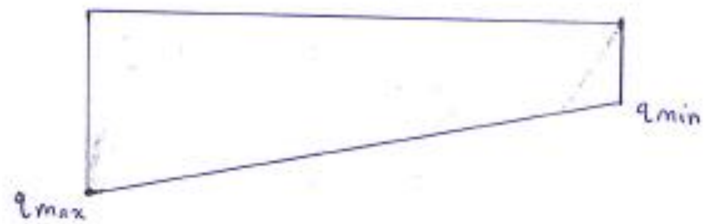
F.S. = (Wfd+W) x m2 / H

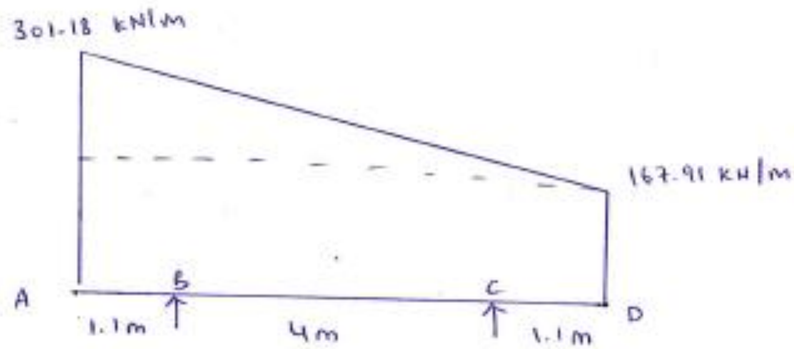
WHERE Wfd = FOUNDATION WEIGHT (kN)
W = EQUIPMENT WEIGHT (kN)
H = LATERAL FORCE (kN)
(DUE TO WIND OR BUNDLE PULLING OR SEISMIC)
m2 = FRICTION COEFFICIENT (SOIL TO CONCRETE)=0.414

CASE	Wfd+W	H	F.S.	MIN F.S.	CHECK
LC2X	903.01	13.53	27.63	1.5	o.k.
LC2Y	903.01	13.53	27.63	1.5	o.k.
LC3X	903.01	119.02	3.14	1.75	o.k.
LC5X	969.48	13.53	29.66	1.5	o.k.
LC5Y	969.48	13.53	29.66	1.5	o.k.
LC6X	969.48	47.62	8.43	1.5	o.k.
LC6Y	969.48	47.62	8.43	1.5	o.k.

DESIGN OF FOOTING







Moment @ B = 0

Total load on beam $= (167.91 \times 6.2) + \left(\frac{1}{2} \times 133.27 \times 6.2\right)$

$= 1454.12$ kN

Distance of resultant load from left end of beam

$$\bar{x} = \frac{(167.91 \times 6.2 \times 3.1) + \left(\frac{1}{2} \times 133.27 \times 6.2 \times \frac{1}{3} \times 6.2\right)}{1454.12}$$

$= 2.81$ m

Distance of Resultant from B = 2.81 − 1.1
= 1.71 m

$M @ B = 0$

$V_C \times 4 = 1454.12 \times 1.71$

$V_C = 621.64$ kN

$V_B = 1454.12 - 621.64$

$= 832.48$ kN

Load intensity at Section x

$$w' = 167.91 + \frac{133.27}{6.2} * x$$

$$V = \int_0^x w' dx$$

$$V = 167.91x + \frac{133.27}{12.4} x^2$$

$$M = \int_0^x V dx$$

$$= \frac{167.91 x^2}{2} + \frac{133.27}{37.4} x^3$$

Shear force Analysis –

. At any section in CD at a distance x from D

$$S_x = -\left(167.91x + \frac{133.27}{12.4} x^2\right)$$

At $x = 0$, $S_x = 0$

At $x = 1.1$, $S_x = -197.7$ kN

At any section in BC distant x from D

$$S_x = 621.64 - \left(167.91x + \frac{133.27}{12.4}x^2\right)$$

At $x = 1.1\text{m}$, $S_x = 423.94\text{ KN}$

$x = 5.1\text{m}$, $S_x = -514.24\text{ KN}$

At section in AB distant x from D

$$S_x = 1454.12 - \left(167.91x + \frac{133.27x^2}{12.4}\right)$$

At $x = 5.1\text{ m}$, $S_x = 318.23\text{ KN}$

$x = 6.2\text{ m}$, $S_x = 0$

<u>Bending Moment Analysis</u>

$$M_c = -\left(\frac{167.91x^2}{2} + \frac{133.27}{37.2}x^3\right)$$

Put $x = 1.1$ ...,

$M_c = -(101.58 + 4.77)$

$= -106.35$

(16

$$M_B = (621.64 \times 4) \cdot \quad \frac{7.91 \times 5.1^2}{2} + \frac{133.27 \times 5.1^3}{37.2})$$

$= (2486.56) - (2658.895)$

$= -172.33\text{ KNm}$

$M_E =$ Point of Contraflexure

Equating S.F. at $E = 0$

$$621.64 = 167.91x + \frac{133.27}{12.4}x^2$$

$$133.27x^2 + 2082.08x - 7708.336 = 0$$

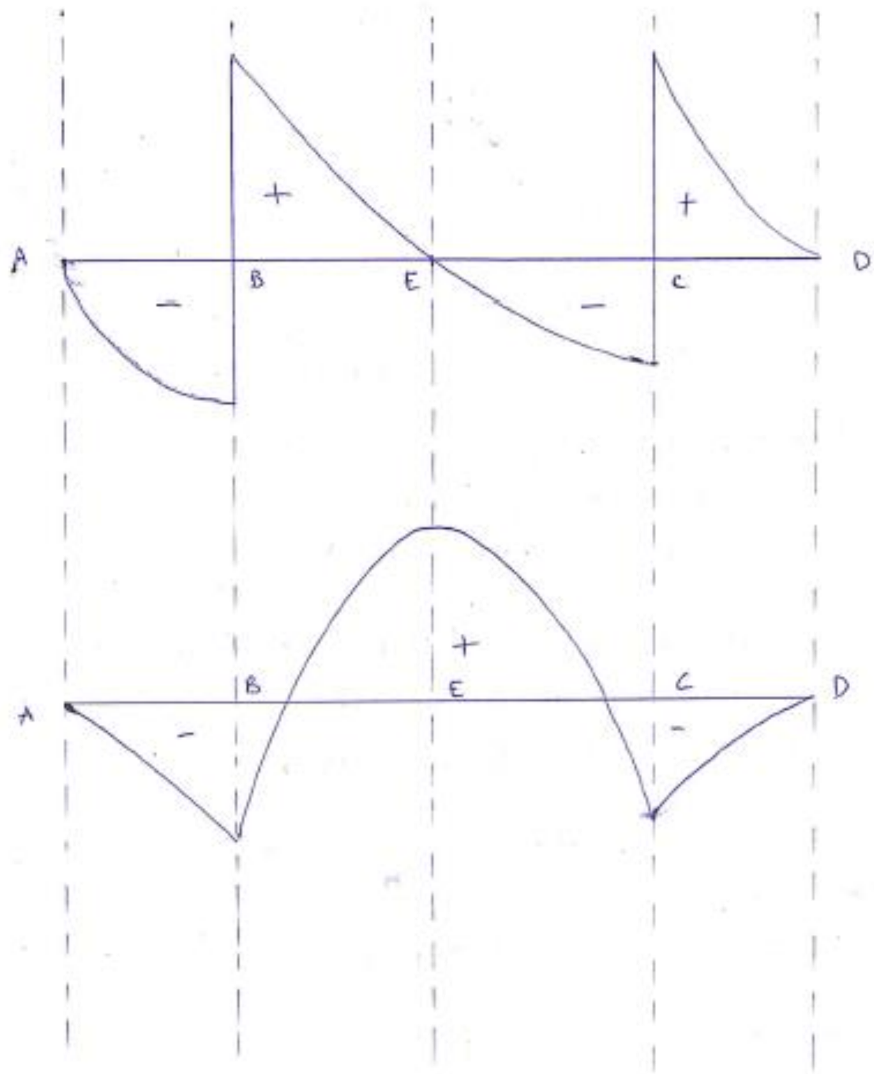
$$x_1 = 3.09\,m$$

$$M_E = (621.64 \times 1.99) - \left(\frac{167.91 \times 3.09^2}{2} + \frac{133.27 \times 3.09^2}{37.2} \right.$$

$$= 329.75\ kNm$$

SHEAR FORCE DIAGRAM

BENDING MOMENT DIAGRAM



CALCULATION FOR MAIN REINFORCEMENT

TOP → Effective depth, d = H_1 - Effective cover

= 425 mm

$$p_t\,req = 50\left[1-\sqrt{1-\frac{4.6\,Mu}{f_{ck}\,b\,d^2}}\right]\frac{f_{ck}}{f_y}$$

$$= \frac{50\times25}{500}\left[1-\sqrt{1-\frac{4.6* 329.75\times10^6}{25\times1000\times425^2}}\right]$$

= 0.46%

$$Ast_{req} = \frac{0.46}{100} * b*d$$

$$= \frac{0.46}{100} * 1000 * 425 = 1955\ mm^2$$

Provide 20mm bars, $A = \frac{\pi}{4} * 20^2$

$= 314.06\ mm^2$

$$spacing = \frac{314.06 * 1000}{1955}$$

= 150 mm

$Ast_{(pro)}$ = 2010.6 mm^2

BOTTOM → $$p_t\,req = 50 * \frac{f_{ck}}{f_y} * \left[1-\sqrt{1-\frac{4.6\,Mu}{f_{ck}\,b\,d^2}}\right]$$

$$= \frac{50\times25}{500}\left[1-\sqrt{1-\frac{4.6\times172.33\times10^6}{25*1000*425^2}}\right]$$

= 0.23%

$$Ast_{req} = \frac{Pt_{req}}{100} * b\,d$$

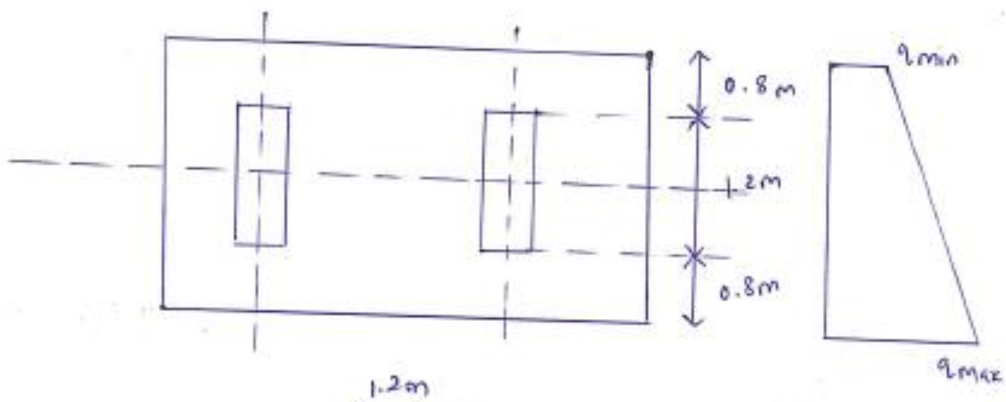
$$= 977.5 \ mm^2$$

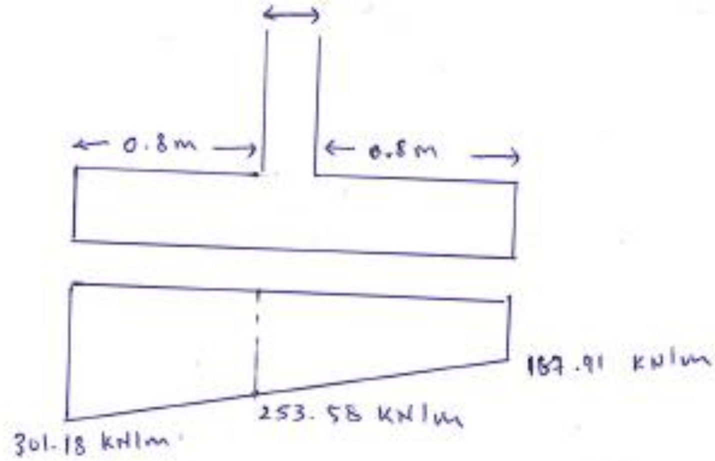
$$\text{spacing} = \frac{1000 * \pi/4 * 12^2}{977.5} = 200 \ mm$$

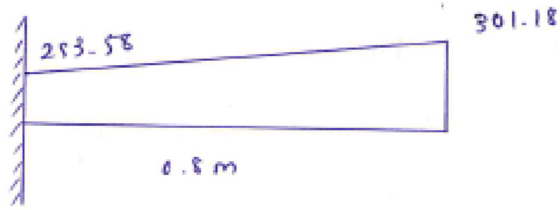
Provide 12mm bars at 200 mm c/c spacing

$Ast_{prov} = 998.4 \ mm^2$

CALCULATION FOR TRANSVERSE REINFORCEMENT







Max Moment $= \left[\frac{1}{2} * 0.8 * (301.18 - 253.58) * \frac{2}{3} * 0.8\right]$

$+ \left[\frac{0.8^2}{2} * 253.58\right]$

$= 91.3$ kNm

$\Rightarrow$ $pt = 50 \frac{fck}{fy}\left[1 - \sqrt{1 - \frac{4.6 Mu}{fck\, bd^2}}\right]$

$= \frac{50 \times 25}{500}\left[1 - \sqrt{1 - \frac{4.6 * 91.3 * 10^6}{25 * 1000 * 425^2}}\right]$

$= 0.12\ \%$

$pt_{min} = 0.12\ \%$.

$\therefore$ $Ast = \frac{0.12}{100} * b * d$

$= 510\ mm^2$

Provide 12 mm dia bars.

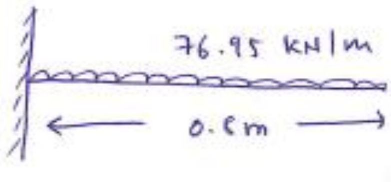
Spacing $= \frac{1000 * \pi/4 * 12^2}{510}$

$= 219.23$ mm

$\Rightarrow$ Providing T-12 @ 210mm c/c

$A_{st\,prov} = 561.6\ mm^2$

TOP



$$\text{Max Moment} = \frac{w l^2}{12}$$

$$= 4.15\ kNm$$

$$p_t = 50\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} b d^2}}\right]\frac{f_{ck}}{f_y}$$

$$= 0.005\%$$

$\Rightarrow$ $P_{t\,min} = 0.12\%$

$$\therefore \quad A_{st} = \frac{0.12}{100} * b * d$$

$$= 510\ mm^2$$

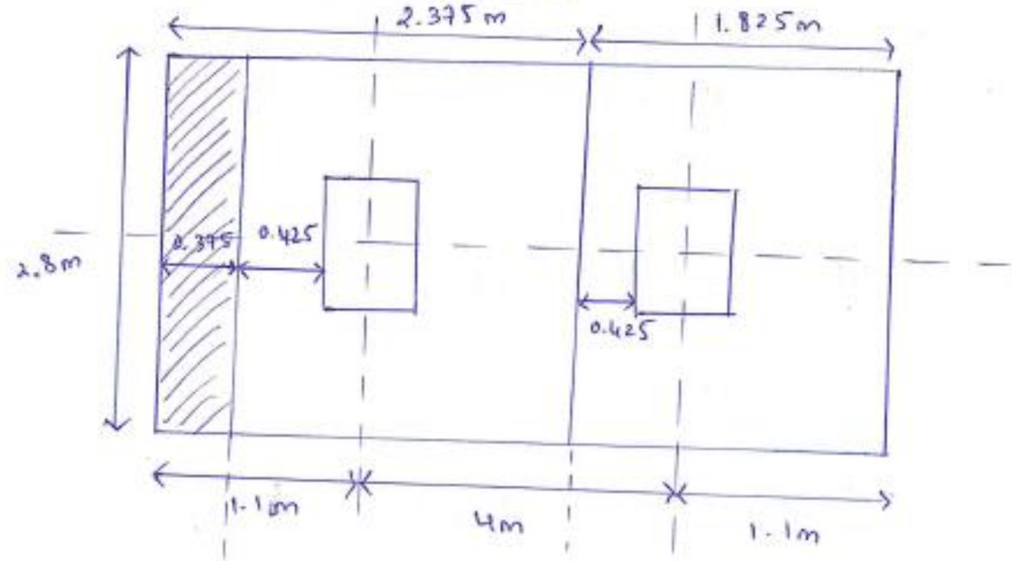
$\therefore$ Spacing of Φ12mm bars

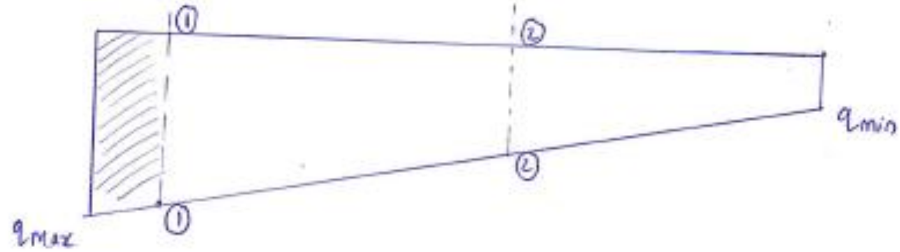
$$\therefore \quad \text{spacing} = \frac{1000 * \pi/4 * 12^2}{510}$$

$$= 219.23\ mm$$

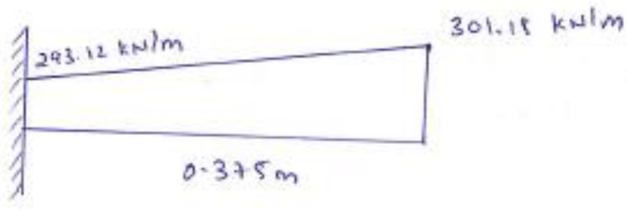
$\Rightarrow$ Provide T-12 @ 210mm c/c

CHECK FOR ONE WAY SHEAR





→ 1 - 1



Shear force at critical section $(V_u) = (0.375 * 293.12) + \frac{1}{2}(0.375)(8.06)$

$= 111.43 \text{kN}$

$$\tau_v = \frac{V_u}{bd}$$

$$= \frac{111.43}{1000 * 425}$$

$$\frac{100\, A_{st}}{bd} = \frac{100 * 997.5}{1000 * 425}$$

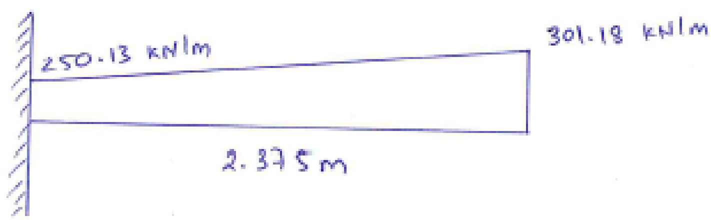
$$= 0.24\ \%$$

From IS:456 2000, Table 19

$$\tau_c = 0.35\ N/mm^2$$

$$\Rightarrow \tau_v < \tau_c \text{ — Okay}$$

2 - 2



Shear force at critical section $= (2.375 * 250.13) + \left(\frac{1}{2} * 51.05 * 2.375\right) - \left(\frac{298.57}{2}\right)$

$$= 84.48\ kN$$

$$\tau_v = \frac{V_u}{bd}$$

$$= \frac{184.48}{1000 * 425}$$

$$= 0.32\ N/mm^2$$

$$\frac{100\,A_{st}}{bd} = \frac{100 * 997.5}{1000 * 425}$$

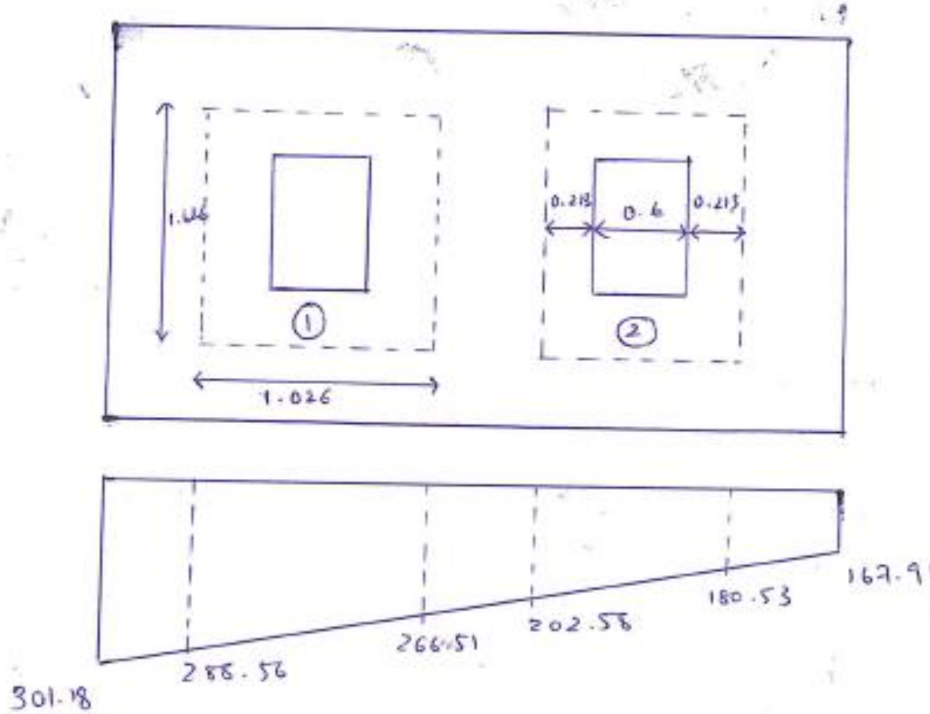
$$= 0.24\%$$

∴ Table 19 – IS:456 2000

$$\tau_c = 0.34$$

$$\Rightarrow \tau_v < \tau_c$$

CHECK FOR TWO WAY SHEAR



① $V_u = \left[\left(\frac{1}{2} * 133.27 * 6.2\right) + (6.2 * 167.91)\right] * 2.8$

$- \left[\left(\frac{1}{2} * 22.05 * 1.026\right) + (266.51 * 1026)\right] * 1.626$

$= 3274.41\ kN$

$$\tau_v = \frac{V_u}{b'd}$$

$$= \frac{3274.41}{(2(1.026+1.626)) * 425}$$

$$= 1.07 \text{ N/mm}^2$$

Cl. 31.6.3.1 → IS 456 : 2000

$$k_s \tau_c = (\beta_c + 0.5) * 0.25\sqrt{f_{ck}}$$

$$= 1.25 \text{ N/mm}^2$$

$$\tau_v < k_s \tau_c$$

(2)

$$V_u = \left[\left(\frac{1}{2} * 133.27 * 6.2\right) + (6.2 * 167.91)\right] * 2.8$$

$$- \left[\left(\frac{1}{2} * 22.05 * 1.026\right) + (180.53 * 1.026)\right] * 1.626$$

$$= 3521.4 \text{ kN}$$

$$\Rightarrow \tau_v = \frac{V_u}{bd} = \frac{3521.4}{2(1.062 + 1626) * 425}$$

$$= 1.14 \text{ N/mm}^2$$

Cl. 31.6.3.1 → IS : 456 : 2000

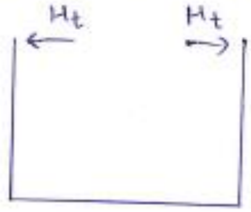
$$k_s \tau_c = (\beta_c + 0.5) * 0.25\sqrt{f_{ck}}$$

$$= 1.25 \text{ N/mm}^2$$

$$\therefore \tau_v < k_s \tau_c$$

DESIGN OF PEDASTAL

(1) Operating + thermal force



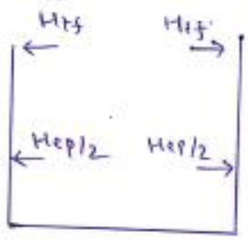
$V_t = H_t = 44.79$ (kN)

$M_{t1} = M_t \times H_2$

$= 44.79 * 4.1$

$= 183.639$ kNm

(2) Operating + Seismic + Thermal



$V_t = \frac{H_{ep}}{2} + \frac{H_{el}}{2} + \frac{H_{tf}}{2}$

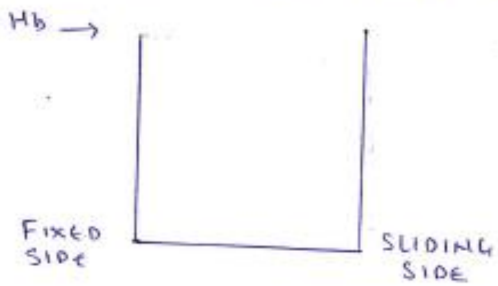
$= \frac{0.117 \times 147.6}{2} + \frac{30.40}{2} + 44.69$

$= 68.60$ KN

$M_t = \frac{H_{ep}}{2} * \frac{4.1}{2} + \left(\frac{H_{el}}{2} + H_{tf}\right) 4.1$

$= 263.59$ KNm

(3) Under Maintenance Condition



$V_t = H_B = 0.86 \times 138.40$

$= 119.024$ KN

$M_t = 119.024 \times 4.1$

$= 488.0$ kNm

$\therefore M = 488.00$ kNm

$M_u = 1.5 \times 488$

$= 732$ KNm

load $P_u = \frac{\text{Empty wt}}{2} - \frac{\text{Moment due to EW}}{L.A.} - \frac{\text{Bundle Moment}}{\text{Area}} + \frac{\text{Weight of Pedastal}}{2}$

$= -43.659$ kN

$\frac{d'}{d} = \frac{97.50}{600} = 0.16$

$\frac{M_u}{f_{ck} b d^2} = \frac{732 * 106}{251 * 1200 * (600)^2}$

$= 0.68$

$\frac{P_u}{f_{ck} b d} = \frac{-43.659 * 10^3}{25 * 1200 * 600}$

$= -0.002$

From SP-16, chart no. 37, 74

$\frac{P_t}{f_{ck}} = 0.050$ $\quad$ $p_t = 1.25\% > P_{t\,min}$ (0.8%)

$A_{st\,req} = 9000\ mm^2$

Provide 25mm bars $\rightarrow \frac{9000}{\frac{\pi}{4} * 25^2} = 18.33$

≈ 20 bars

spacing $= \frac{1200}{7} = 171.42$ mm

≈ 170mm c/c

$A_{st\,provided} = 9817.47\ mm^2$

p_t provided $= 1.36\%$

Check for Slenderness

$l = 4100$ mm

$l_{eff} = 2 * 4100$

$= 8200$ mm

About Major Axis

$\Rightarrow \frac{8200}{1200} = 6.833 < 12 \rightarrow$ OK

About Minor Axis

$\Rightarrow \frac{8200}{600} = 13.66 > 12 \rightarrow$ Slender Column

Clause 39.7.1. IS:456 : 2000

$$e_z = \frac{1200}{2000}\left(\frac{8200}{1200}\right)^2 = 29.00 \text{ mm}$$

$$e_y = \frac{600}{1200}\left(\frac{8200}{600}\right)^2 = 57 \text{ mm}$$

Additional Moments $\rightarrow$ $M_{az} = P_u * e_{az}$

$= 43.659 * 29$

$= 1.27$ kNm

$M_{ax} = 43.659 * 57$

$= 2.49$ kNm

Hence Applying reduction factor,

$$K = \frac{P_{uz} - P_u}{P_{uz} - P_b}$$

Calculating K, $K > 1 \Rightarrow$ Taking $K = 1$

$M_{oz} = 1.27$ kNm

$M_{ax} = 2.49$ kNm

$\therefore$ Final moments

$M_{ux} = 2.49 + 732$

$= 734.49$ kNm

$M_{uz} = 1.27 + 2.13$

$= 3$ kNm

$p_{t\,prov.} = 1.36\%$

$\Rightarrow \dfrac{p_t}{f_{ck}} = 0.050$

<u>About</u> <u>z-z</u> <u>axis</u> $\rightarrow \dfrac{d'}{d} = \dfrac{97.5}{1200} = 0.081$

$\dfrac{P_u}{f_{ck}bd} = 0.02$; $\dfrac{M_u}{f_{ck}bd^2} = 0.079$

$\therefore$ SP-16, chart 73

$M_{uz1} = \dfrac{0.079 \times 25 \times 600 \times 1200^2}{10^6}$

$= 1728$ kNm > 734 kNm

— OK

<u>About</u> <u>x-x</u> <u>axis</u> $\rightarrow \dfrac{d'}{d} = \dfrac{97.5}{600} = 0.163$

$$\frac{P_u}{f_{ck} b d} = 0.02 \quad , \quad \frac{M_u}{f_{ck} b d^2} = 0.068$$

Hence , SP-16 chart 74

$$M_{ux1} = \frac{0.068 \times 25 \times 1200 \times 600^2}{(10)^6}$$

$$= 750 \text{ KNM} > 732 \text{ KNm} \rightarrow \underline{\underline{OK}}$$

Clause 39.6 → IS456 : 200

$$\left(\frac{M_{uz}}{M_{uz1}}\right)^{\alpha n} + \left(\frac{M_{ux}}{M_{ux1}}\right)^{\alpha n} \leq 1$$

$$\left(\frac{3}{1738}\right)^{\alpha n} + \left(\frac{734}{756}\right)^{\alpha n} \leq 1 \Rightarrow \text{Safe}$$

Hence : 20 T-25 mm @ 170 mm c-c

<u>Transverse</u> <u>Reinforcement</u>

Pitch → Cl. 26.5.3.2 → IS 456 : 2000

(i) 600 mm

(ii) 16 x 25 = 400 mm

(iii) 300 mm

⇒ Provide → 200 mm

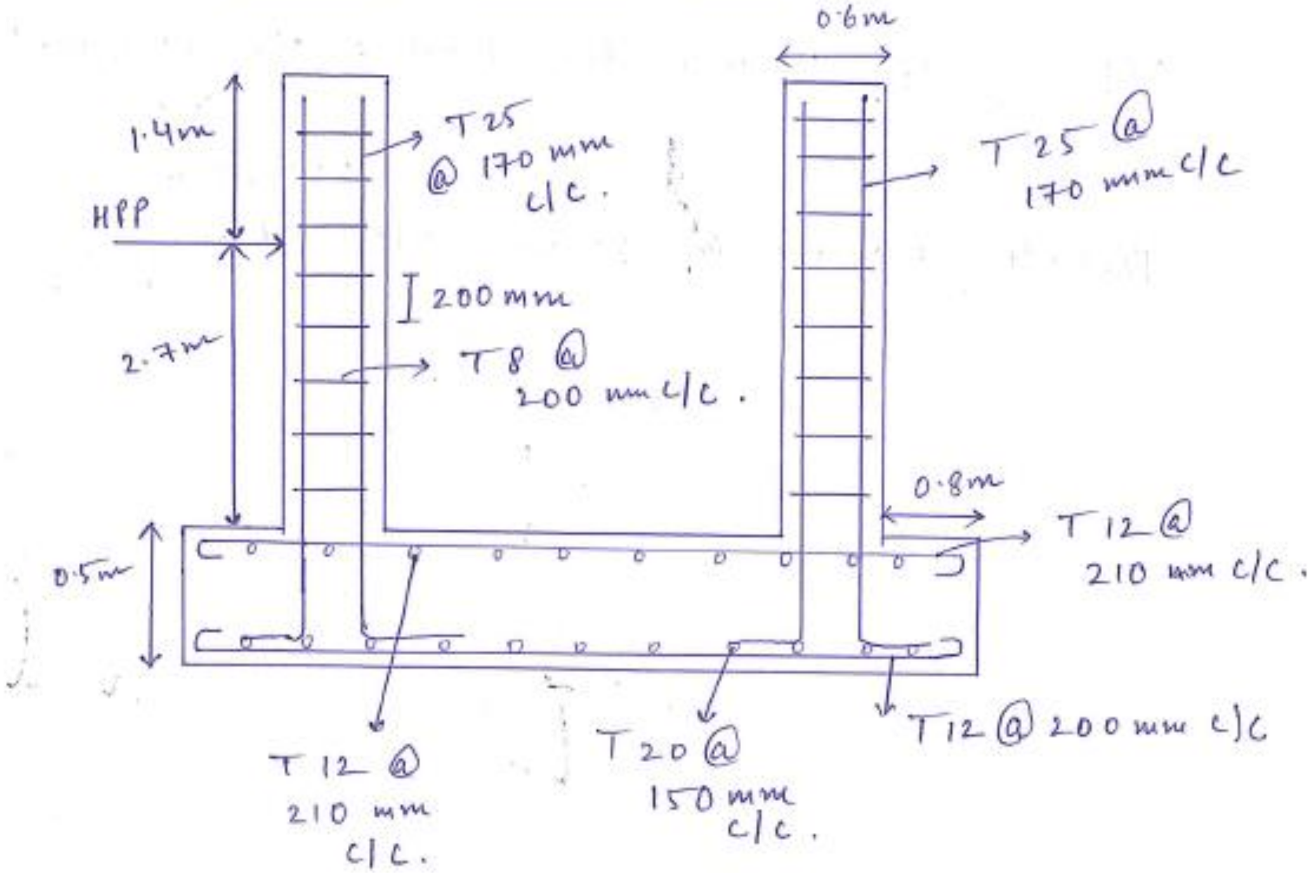
Dia → Cl. 26.5.3.2 → IS 456 2000

(i) $\frac{1}{4} \times 25 \rightarrow 6.25$ mm

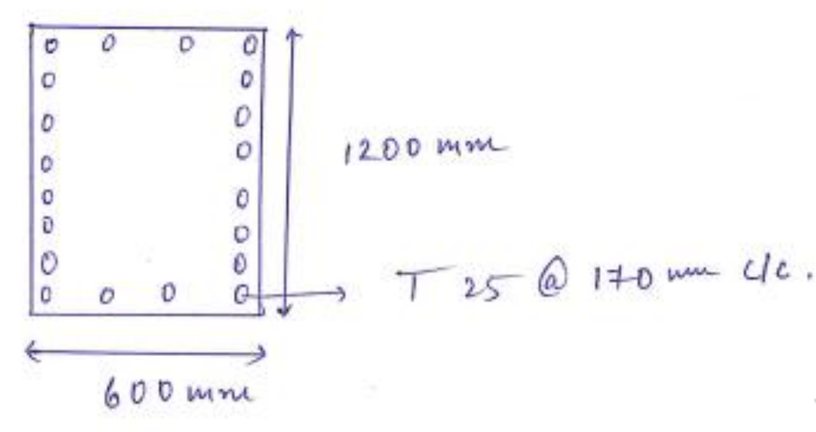
(ii) > 6 mm

⇒ Provide T-8 Ties @ 200 mm c/c

FOOTING RE-BAR ARRANGEMENT



PEDESTAL REBAR ARRANGEMENT



DESIGN OF HORIZONTAL VESSEL AND HEAT EXCHANGER FOUNDATION AND PEDASTAL (COMBINED FOOTING)

1. GENERAL

1.1-Specification for design

The design calculations are in accordance with design philosophy for vertical equipment foundation.

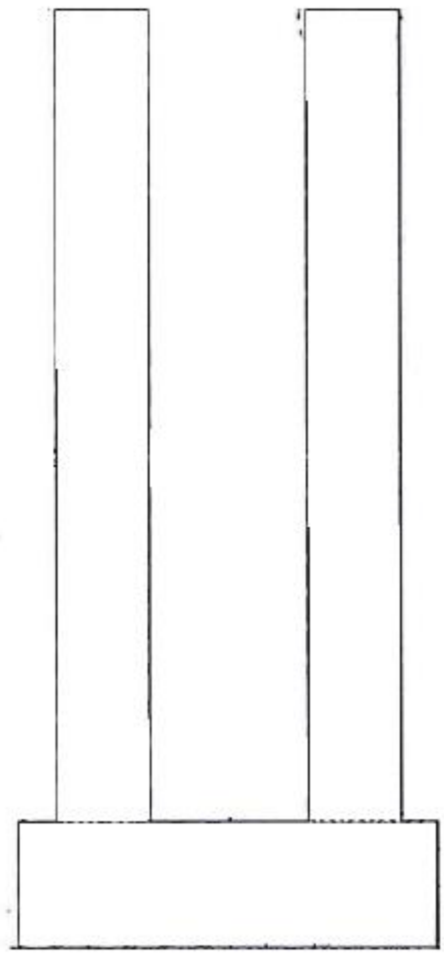
1.2-Codes and References used

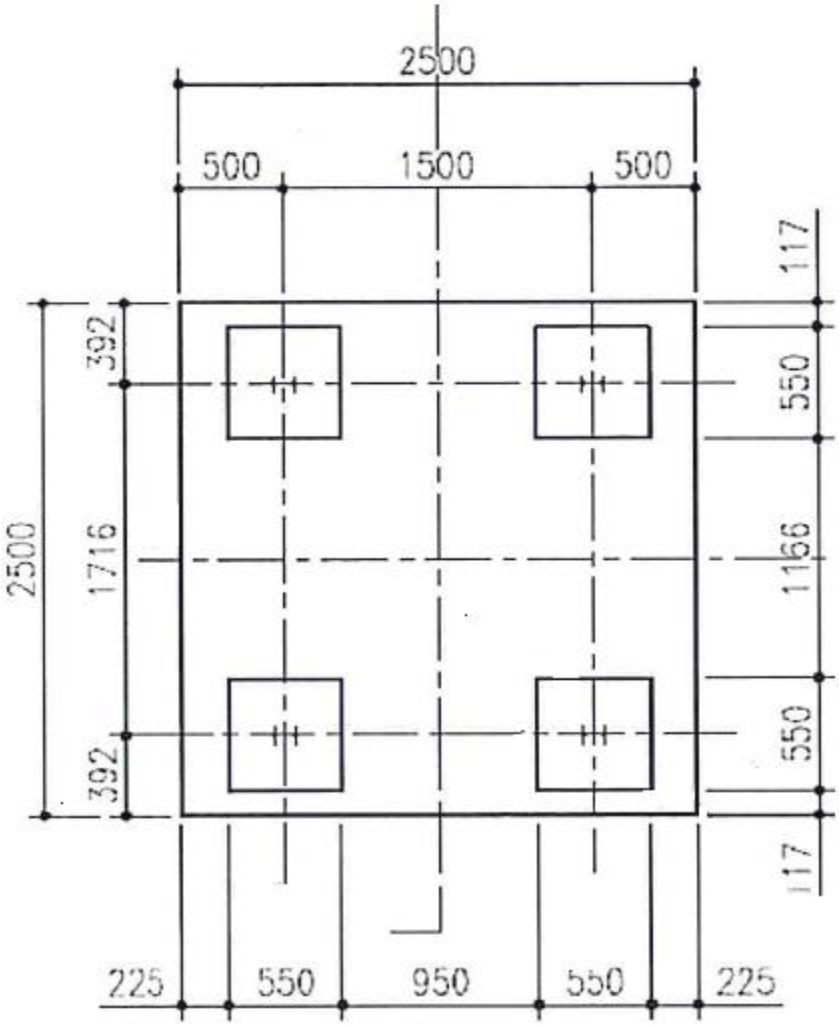
IS 456:2000 – code of practice for plain and reinforced concrete

ACI 351.2-94: foundations for static equipment

1.3-Design Parameters

- Structural concrete
  - ✓ Unit weight (density) γ_c = 25 KN/m^3
  - ✓ Concrete grade (f_{ck}) = 25 MPa
- Reinforcing steel grade (f_y) = 500 MPa
- Footing side concrete cover E-W dir. = 75mm
- Footing side concrete cover N-S dir. = 75mm
- Footing top concrete cover = 75mm
- Footing bottom concrete cover= 100mm
- Soil parameters
  - ✓ Net soil bearing capacity = 180 KN/m^2
  - ✓ unit weight = 19 kN/m^3
- Depth of foundation = 3.2m below HPP




2500
500
1500
500
117
392
550
2500
1716
1166
550
392
117
225
550
950
550
225

2. LOADING DATA

- **Empty weight (We)** = 95.40 kN
- **Operating weight (Wo)=** 98.30 kN; vertical seismic load = 6.6kN

Wo = 98.3– (0.3 * 6.6)= 96.32 kN

- **Hydrostatic test weight (Wh)** = 121.3 kN
- **Tube bundle weight (Wt)** = 32.6 kN
- **Wind load**

Max shear at base (Hwl)= 3.40 kN

Moment at base = 0.7 KNm

Since pedestal is of considerable height above HPP wind load on pedestal has to be considered as per IS:875 (PART3)

Design wind speed Vz = K1*K2*K3*Vb

= 1*1*1*39

= 39 m/s

Design wind pressure Pz = 0.6 *Vz^2

= 912.60 N/m^2

Total wind force =F= Cf*A*Pz

Hwp1= total wind force along X= 2*(0.55+0.55)*2.7*Cf*Pz= 10.84 kN

Hwp2= total wind force along Y= 2*(0.55+0.55)*2.7*Cf*Pz= 10.84kN

Hwp=max(Hwp1, Hwp2)= 10.84 kN

Total wind load Hw =10.84+3.40= 14.24 KN

- **Foundation weight(Wfd)**

Weight of footing (Wf)= 2.5*2.5*0.5* γ**c** = 78.12 kN

Weight of pedestal (Wp) = 4* (2.7+2.7)*0.55*0.55*γ**c** = 163 .35 kN

Weight of soil on footing (Ws) = (2.5*2.5-4*0.55*0.55)*2.7* γ**s** =258.55KN

Buoyant force (Vf) = 2.5*2.5*(3.2-.02)* 9.8= 183.75 kN

Wfd = Wf +Ws+ Wp –Vf = 316.27 kN

- **Seismic load**

Shear at base:-9.90 KN
Moment at base:- 2.00 KNmEarthquake load (Shear force and moment due to earthquake at top of pedestal) on Equipment

are supplied by Equipment Department.

- Seismic forces on pedestals are calculated as a rigid body consideration using
  Simplified Method [Equivalent Static Lateral Force Method] as specified in Clause
  10.3.1 of IS 1893 (Part 4): 2005.
  • Category – 2 shall be adopted as per Table 5 of IS 1893 (Part 4): 2005 for horizontal
  vessel / heat exchanger foundation.
  • Damping for concrete structure shall be considered 5% as per table 7 of IS 1893,
  Part IV.
  • Importance factor, I shall be taken as 1.75 as per Table 2 of IS 1893 (Part 4): 2005
  for Category - 2.
  • Response reduction factor R, shall be taken as 3 considering Ordinary RC moment
  resisting frame (OMRF) as given in Table 3 of IS 1893 (Part 4): 2005.

Total Earthquake Load acting in specified direction
V = Ah x W
where,

W = Seismic weight of member
Ah = Seismic Co-efficient
= (Z/2) x (Sa/ g) x (I/ R)
= (0.16/2) x (2.5) x (1.75/ 3) = 0.117
Sa/g = 2.5 as per Fig-2 Response spectra for rock and soil sites for 5% damping IS 1893 (Part-1).

kp = SEISMIC FACTOR FOR PEDESTAL = **0.117**
Kf = SEISMIC FACTOR FOR FOOTING = **0**
ks = SEISMIC FACTOR FOR SOIL ON FOOTING = **0**

He = Hel + Hep +Hef +Hes
= (Hel) + (kp x Wp) + (kf x Wf) + (ks x Wso)
= 9.9+ (0.117 * 163.35) + 0 + 0
= 29 KN

3. OVERTURNING MOMENT

Mw	0.7 + (14.24*5.9) = 84.72 kN m
Me	2+(9.9*5.9)+(163.35*0.117*3.2)+0+0 = 121.56 kN m
Mb	0.86*32.6*6.1 = 171.04 kN m
Mse	We*eccentricity = 95.4*0.706 = 67.35 kN m
Mso	Wo*eccentricity=96.32*.706 = 68 kNm
Msh	Wh*eccentricity= 121.3* 0.706 = 85.64 kNm

Where,

Mw- CAUSED BY WIND LOAD
Me- CAUSED BY SEISMIC LOAD
Mb- CAUSED BY TUBE BUNDLE PULLING FORCE Mb
Mse- CAUSED BY ECCENTRIC POSITION OF C.G.(EMPTY)
Mso- CAUSED BY ECCENTRIC POSITION OF C.G.(OPER)
Msh- CAUSED BY ECCENTRIC POSITION OF C.G.(HYD. TEST)

4. **LOAD COMBINATIONS**

Permissible soil bearing pressure referring IS:1904 CL 15.1.7 and IS : 1893 :-

LOAD COMBINATIONS	**PERM. STRESS FACTOR**
LC1 -ERECTION LOAD	**1**
LC2- ERECTION WITH WIND LOAD	**1.25**
LC3 -MAINTENANCE COND. WITH TUBE BUNDLE PULLING FORCE	**1.25**
LC3 -OPERATING LOAD	**1**
LC4- OPERATING WITH WIND LOAD	**1.25**
LC5 -OPERATING WITH SEISMIC LOAD	**1.25**
LC6 -HYDROSTATIC TEST WEIGHT	**1**
LC7- HYDROSTATIC TEST WEIGHT WITH 25 %WIND LOAD	**1.25**

CASE	CONDITION	Wfd (kN)	Wx(kN)	Px(kN)	Mx(kN m)	My(kN m)	Mse(k N m)
LC1	empty	316.2 7	95.4	411.67			67.35
LC2	empty + wind	316.2 7	95.4	411.67	84.72	84.72	67.35
LC3	empty + bundle	316.2 7	95.4	411.67	171.04	171.04	67.35
LC4	operating	316.2 7	96.32	412.59			68

LC5	operating + wind	316.27	96.32	412.59	84.72	84.72	68
LC6	operating + seismic	316.27	96.32	412.59	121.56	121.56	68
LC7	hydrotest	316.27	121.3	437.57			85.64
LC8	test + wind	316.27	121.3	437.57	21.18	21.18	85.64

5. STABILITY ANALYSIS

1. Check for soil bearing pressure

For LC1,LC4, LC7,LC2X,LC3X,LC5X,LC6X,LC8X

Smax/min =(Wfd+W)/Af*(1±6*ex/A5)

For LC2Y , LC5Y, LC6Y, LC8Y

Smax/min =(Wfd+W)/Af*(1±6*ey/B1)

	FORCE			ECCENTRIC DISTANCE				SOIL PRESSURE		
CASE	Wfd+W	Mx	My	ex	ey	ex/A5	ey/B1	Smax	Smin	ALLOW
LC1	411.67	0	67.35	0.164	0	0.065	0	33.02	14.40	240.8
LC2x	411.67	0	84.72	0.206	0	0.082	0	35.43	12.00	285.8
LC2y	411.67	84.72	67.35	0.164	0.206	0.065	0.08	33.02	14.40	285.8
LC3x	411.67	0	238.39	0.579	0.000	0.232	0.00	56.67	9.24	285.8
LC4	412.59	0	68	0.165	0.000	0.066	0.00	33.17	14.37	240.8
LC5x	412.59	0	84.72	0.205	0.000	0.082	0.00	35.48	12.05	285.8
LC5y	412.59	84.72	68	0.165	0.205	0.066	0.08	33.17	14.37	285.8
LC6x	412.59	0	121.56	0.295	0.000	0.118	0.00	40.57	6.96	285.8
LC6y	412.59	121.56	68	0.165	0.295	0.066	0.12	33.17	14.37	285.8
LC7	437.57	0	85.64	0.196	0.000	0.078	0.00	37.05	13.37	240.8

LC8x	437.57	0	21.18	0.048	0.000	0.019	0.00	28.13	22.28	285.8
LC8y	437.57	21.18	85.64	0.196	0.048	0.078	0.02	37.05	13.37	285.8

2. Check for overturning

FS=L/(2*e)

WHERE e = ECCENTRICITY DISTANCE (m) = M / (Wfd+W)

M = OVERTURNING MOMENT (kN m)
Wfd = FOUNDATION WEIGHT (kN)
W = EQUIPMENT WEIGHT (kN)
L = FOOTING DIMENSION (m)

CASE	M	Wfd+W	e	L	F.S.	MIN F.S.	CHECK
LC2X	84.72	411.67	0.206	2.5	6.07	1.5	o.k.
LC2Y	84.72	411.67	0.206	2.5	6.07	1.5	o.k.
LC3X	238.39	411.67	0.579	2.5	2.16	2	o.k.
LC5X	84.72	412.59	0.205	2.5	6.09	1.5	o.k.
LC5Y	84.72	412.59	0.205	2.5	6.09	1.5	o.k.
LC6X	121.56	412.59	0.295	2.5	4.24	1.5	o.k.
LC6Y	121.56	412.59	0.218	2.5	5.73	1.5	o.k.

3 Check for sliding-

F.S. = (Wfd+W) x m2 / H

WHERE Wfd = FOUNDATION WEIGHT (kN)
W = EQUIPMENT WEIGHT (kN)
H = LATERAL FORCE (kN)(DUE TO WIND OR SEISMIC)
m2 = FRICTION COEFFICIENT (SOIL TO CONCRETE)=0.414

CASE	Wfd+W	H	F.S.	MIN F.S.	CHECK
LC2X	411.67	14.24	11.97	1.5	o.k.
LC2Y	411.67	14.24	11.97	1.5	o.k.
LC3X	411.67	32.6	5.23	1.75	o.k.
LC5X	412.59	14.24	12.00	1.5	o.k.
LC5Y	412.59	14.24	12.00	1.5	o.k.
LC6X	412.59	29	5.89	1.5	o.k.
LC6Y	412.59	29	5.89	1.5	o.k.

PIPERACKS

Classification of Pipe racks: - Pipe racks can be classified based on the following criteria:

1. Material
2. Location
3. Geometry

Material:

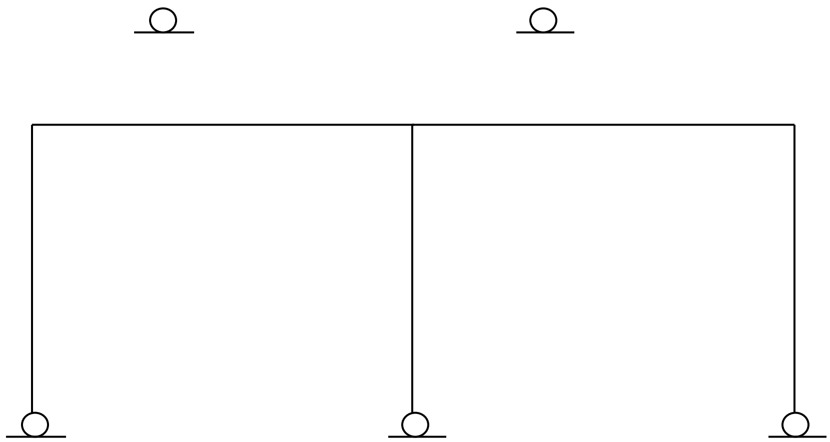
1. Steel pipe rack
2. RCC pipe rack
3. Combination of both steel and RCC

Location:

1. Main rack
2. Sub rack

Geometry:

Single bay pipe rack



Twin bays pipe rack

```
|-----------------------------------------------------------------------------|
|  Member Number:   2548                                                      |
|  Member Section:  ST   UC254X254X73    (BRITISH SECTIONS)                   |
|  Status: PASS  Ratio:   0.168  Critical Load Case:   323  Location:     0.45 |
|  Critical Condition: Sec. 9.3.2.2 (Y)                                       |
|  Critical Design Forces:  (Unit: KN    METE)                                |
|      FX:     204.280E+00 C     FY:     -15.493E+00      FZ:     -6.000E+00  |
|      MX:      21.691E-03       MY:       2.700E+00      MZ:     -7.083E+00  |
|-----------------------------------------------------------------------------|
|  Section Properties:     (Unit:  CM  )                                      |
|  AXX:      93.100E+00          IZZ:      11.400E+03          RZZ:     11.066E+00|
|  AYY:      21.853E+00          IYY:       3.910E+03          RYY:      6.481E+00|
|  AZZ:      72.306E+00          IXX:      57.625E+00           CW:    561.970E+03|
|  ZEZ:     897.285E+00          ZPZ:     992.000E+00                           |
|  ZEY:     307.149E+00          ZPY:     465.000E+00                           |
|-----------------------------------------------------------------------------|
|  Slenderness Check:    (Unit:  METE)                                        |
|  Actual Length:        1.800E+00                                            |
|  Parameters:      LZ:         1.800E+00  LY:        1.800E+00               |
|                   KZ:             1.000  KY:            1.000               |
|  Actual Ratio:  27.78 Allowable Ratio: 180.00  LOAD:   304 FX:    34.963E+00 C |
|-----------------------------------------------------------------------------|
| Section Class:      Plastic; Flange Class:      Plastic; Web Class:     Plastic |
|-----------------------------------------------------------------------------|

                  STAAD.PRO CODE CHECKING - IS-800 2007 (V2.0)
                  ***********************************************

|-----------------------------------------------------------------------------|
|  Member Number:   2548                                                      |
|  Member Section:  ST   UC254X254X73    (BRITISH SECTIONS)                   |
|-----------------------------------------------------------------------------|
|  Tension:    (Unit:KN    METE)                                              |
|  Parameters:      FYLD:       250.000E+03       FU:      410.000E+03        |
|                   NSF:            1.000    ALPHA:            0.800    DBS: 0 |
|  Capacity:        2.116E+03           As per sec. No.:Cl. 6.2               |
|  Actual Design Force:      -51.084E+00      LC:     309                     |
|-----------------------------------------------------------------------------|
|  Compression:    (Unit:KN    METE)                                          |
|  Buckling Class:    Major: b    Minor: c    As per Sec. No.:Cl. 7.1.2.2     |
|  Capacity:        1.969E+03           As per sec. No.:Cl. 7.1.2             |
|  Actual Design Force:      207.280E+00      LC:     323                     |
|-----------------------------------------------------------------------------|
|  Shear:    (Unit:KN  )                                                      |
|  Major Axis:  Actual Design Force:    -15.987E+00  LC:   310  Loc:     0.000E+00|
|               Capacity:       286.741E+00    As per sec. No.:Cl. 8.4.1      |
|  Minor Axis:  Actual Design Force:     -6.000E+00  LC:   319  Loc:     0.000E+00|
|               Capacity:       948.775E+00    As per sec. No.:Cl. 8.4.1      |
|-----------------------------------------------------------------------------|
|  Bending:    (Unit:KN    METE)                                              |
|  Parameters:   Laterally Unsupported    KX:   1.00  LX:   1.800E+00  Simp Suppr |
|  Major Axis:  Actual Design Force:     -7.194E+00  LC:   310  Loc:   900.000E-03|
|               Capacity:       221.303E+00    As per sec. No.:Cl. 8.2.2      |
|  Minor Axis:  Actual Design Force:      2.700E+00  LC:   319  Loc:     1.200E+00|
|               Capacity:        83.768E+00    As per sec. No.:Cl. 8.2.1.2    |
|-----------------------------------------------------------------------------|
|  Combined Interaction:                                                      |
|  Parameters:  PSI: 1.00   CMX:    1.000   CMY:    1.000   CMZ:    1.000     |
|  Interaction Ratio:      0.168    As per sec. No.:Sec. 9.3.2.2 (Y)          |
|  LC:     323    Loc:      450.000E-03                                       |
|-----------------------------------------------------------------------------|
|  Checks              Ratio   Load Case No.      Location from Start         |
|                                                                             |
|  Tension               0.024     309                     0.000E+00          |
|  Compression           0.105     323                     0.000E+00          |
|  Shear Major           0.056     310                     0.000E+00          |
|  Shear Minor           0.006     319                     0.000E+00          |
|  Bend Major            0.033     310                   900.000E-03          |
|  Bend Minor            0.032     319                     1.200E+00          |
|  Sec. 9.3.1.3          0.098     323                     0.000E+00          |
|  Sec. 9.3.2.2 (Z)      0.150     323                   450.000E-03          |
```

MEMBER DESIGN OF PIPE RACK

Member Section : UC 254 x 254 x 73

$H = 254.1\ mm$

$B = 254.6\ mm$

$t_w = 8.6\ mm$

$t_f = 14.2\ mm$

$r = 12.7\ mm$

$A = 93.1\ cm^2$

Actual length = 1.8 m

Effective length = L_{LT} = 1.8 m

$E = 2 \times 10^5\ N/mm^2$

$r_y = 64.8\ mm$

$h_f = H - t_f = 239.9\ mm$

$t_f = 14.2\ mm$

$$f_{crb} = \frac{1.1\pi^2 E}{(L_{LT}/r_y)^2}\left[1 + \frac{1}{20}\left(\frac{L_{LT}/r_y}{h_f/t_f}\right)^2\right]^{0.5}$$

$$= \frac{1.1\pi^2 \times 2 \times 10^5}{(1800/64.8)^2}\left[1 + \frac{1}{20}\frac{(1800/64.8)^2}{(239.9/14.2)^2}\right]^{0.5}$$

$$= 2998.2\ N/mm^2$$

$$\lambda_{LT} = \sqrt{\frac{f_y}{f_{crb}}}$$

$$= 0.289$$

$$\phi_{LT} = 0.5\left[1 + \alpha_{LT}(\lambda_{LT} - 0.2) + \lambda_{LT}^2\right]$$

$$= 0.5\left[1 + 0.21(0.289 - 0.2) + (0.289)^2\right]$$

$$\phi_{LT} = 0.55$$

$$f_{bd} = \frac{f_y}{\left\{\phi_{LT} + \left[\phi_{LT}^2 - \lambda_{LT}^2\right]^{0.5}\right\} \cdot \gamma_{m0}}$$

$$= 222.98 \ N/mm^2$$

$B_b = 1 \rightarrow$ for Plastic section

$$\therefore M_y = B_b Z_p f_{bd}$$

$$= 103.68 \ KNm$$

Clause 8.2.1.2, Pg 53.

$$M_d \leq \frac{1.2 \times Z_e \times f_y}{\gamma_{m0}}$$

$$M_y \leq \frac{1.2 \ Z_{ey} \ F_y}{\gamma_{m0}}$$

$$103.68 \leq \frac{1.2 \times 307.149 \times 10^3 \times 250}{1.1}$$

$103.68 \leq 83.768 \rightarrow$ which isnt true

M_y (minor axis) $= 83.768$ KNm

About Major Axis

$r_{xx} = 11.07\ cm = 110.7\ mm$

$I_{xx} = 11420\ cm^4$

$f_{crb} = 8400.48\ N/mm^2$

$$\lambda_{LT} = \sqrt{\frac{f_y}{f_{crb}}} = 0.17$$

$$\phi_{LT} = 0.5\,[1 + 0.21\,(0.17 - 0.2) + (0.17)^2]$$
$$= 0.5113$$

$$\chi_{LT} = \frac{1}{\left\{\phi_{LT} + [\phi_{LT}^2 - \lambda_{LT}^2]^{0.5}\right\}}$$

$$\chi_{LT} = 1$$

$$f_{bd} = \frac{\chi_{LT} \times f_y}{\gamma_{mo}} = 227.27\ N/mm^2$$

$$M_x = B_b Z_p f_{bd}$$
$$= 225.45\ kNm$$

COMPRESSION

$$\frac{h}{b_f} = \frac{254.1}{254.6} = 0.99 \leq 1.2$$

$$t_f \leq 100\ mm$$

Minor axis → Buckling c

Major axis → Buckling b

$r_{min} = 64.8\ mm$, $L = 1.8\ m$

$$f_{cc} = \frac{\pi^2 E}{(KL/r_{min})^2}$$

$$= \frac{\pi^2 \times 2 \times 10^5}{(1800/64.8)^2} = 2558.2\ N/mm^2$$

$$\lambda = \sqrt{\frac{f_y}{f_{cc}}} = 0.313$$

$\alpha = 0.49 \rightarrow$ Class c $\rightarrow$ Table 7

$$\phi = 0.5[1 + \alpha(\lambda - 0.2) + \lambda^2]$$

$$= 0.5[1 + 0.49(0.313 - 0.2) + 0.313^2]$$

$$\phi = 0.575$$

$$f_{cd} = \frac{f_y/\gamma_{m0}}{\phi + \sqrt{\phi^2 - \lambda^2}} = 214.55\ N/mm^2$$

$$P_d = A_e f_{cd}$$

$$= 93.1 \times 214.55$$

$$P_d = 1997.46\ N$$

<u>SHEAR</u>

Major Axis — Clause 8.4.1 $\rightarrow$ IS : 800 : 2007

$$V_n = \frac{A_v f_{yw}}{\sqrt{3}} = \frac{h\, t_w \times f_{yw}}{\sqrt{3}}$$

$$V_n = \frac{254.1 \times 8.6 \times 250}{\sqrt{3}}$$

$$= 315.415 \text{ kN}$$

$$V_d = \text{design Strength} = \frac{V_n}{\gamma_{mo}} = \frac{315.415}{1.1}$$

$$= 286.74 \text{ kN}$$

Minor Axis — Clause 8.4.1 → IS : 800 - 2007

$$A_v = 2 b t_f$$

$$= 2 \times 254.6 \times 14.2$$

$$= 7230.64 \text{ mm}^2$$

$$V_n = \frac{A_v f_y}{\gamma_{mo}}$$

$$= \frac{7230.64 \times 250}{\sqrt{3}}$$

$$V_n = 1043.65 \text{ kN}$$

$$V_d = \frac{V_n}{\gamma_{mo}} = 948.775 \text{ kN}$$

CHECKS (compression)

$$\text{Ratio} = \frac{207.28}{1997.46} = 0.104$$

Shear Major =

$$\text{Ratio} = \frac{15.98}{286.74} = 0.056$$

Shear Minor

$$\text{Ratio} = \frac{6}{948.775} = 0.006$$

Bend Major

$$\text{Ratio} = \frac{7.194}{225.45} = 0.032$$

Bend Minor

$$\text{Ratio} = \frac{2.7}{83.768} = 0.032$$

Hence OK

PORTAL FRAMES

INFRERENCE

Figure 1 – this figure shows the BM diagram for two similar frames i.e. having same stiffness of members and same dimensions of members, subjected to similar loading condition (UDL of 1kN/m) with end condition being fixed in one case and pinned in other . red line represents BM diagram in case of pinned ends and blue line in case of fixed ends

Figure 2– this figure shows the BM diagram for two similar frames i.e. having same stiffness of members and same dimensions of members, subjected to similar loading condition (point of 1kN) with end condition being fixed in one case and pinned in other . red line represents BM diagram in case of pinned ends and blue line in case of fixed ends

Figure 3- this figure shows the bending moment diagram for fixed case only when UDL of 1 kN/m and point load of 1kN acts simultaneously.

Figure 4- this figure shows the bending moment diagram for fixed case only when UDL of 1 kN/m and point load of 1kN acts simultaneously.

Figure 5– this figure shows the BM diagram for two similar frames i.e. having same stiffness of members and same dimensions of members, subjected to similar loading condition (UDL of 1kN/m and a point of 1kN acting simultaneously) with end condition being fixed in one case and pinned in other . Red line represents BM diagram in case of pinned ends and blue line in case of fixed ends

It can be seen from the figures that pinned beam has to designed for greater value of moments than fixed beams

As seen in CASE 2&3 the value of moment for which the member is to be designed , when the ends of the frame are fixed is 0.625 knm . but when the ends of the frame are fixed the beam is to be designed for a greater moment value of 1 knm.

Hence size of member required for fixed case will be less as compared to pinned . however in fixed beam, moments get introduced at the fixed end , which is zero in case of pinned frames. Hence the foundation size in fixed frames has to larger as compared to pinned frames.