

Analysis and Design of Sump Pit

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1.0 GENERAL

This document covers the Design Calculation of Sump Pit

1.1 Scope

This document contains the following

- a) Design Basis comprising of description of the structure, structural analysis methodology
- b) Load Calculation
- c) STAAD Plate Model comprising of Tank framing sketches and input file.

1.2 Units of Measurement

SI units are followed in the design calculations.

1.3 References

The following codes and standards with the latest revisions and drawings have been referred for the structural analysis and design.

1.3.1 Codes and Standards

Code	Description
IS: 456 - 2000	Code of practice for Plain & Reinforced Concrete
IS: 3370 (Part I & II) – 2009 & IS: 3370 (Part III & IV) – 1967	Code of practice for Concrete structures for storage of Liquids
SP: 16-1980	Design aids for Reinforced concrete to IS: 456-1978
IS: 875-1987	Code of Practice for Design loads (other than Earthquake) for Buildings & Structures. (Part 1 to 5)
IS: 1893 (Part I) - 2002	Criteria for Earthquake Resistant Design of Structures (General provisions and buildings)
IS: 1893 (Part 2) - 2014	Criteria for Earthquake Resistant Design of Structures (Liquid retaining tanks)
IS: 800-1984	Code of practice for General construction of steel.
IS 13920 - 1993	Ductile Detailing of Reinforced Concrete Structures Subject to Seismic Forces

1.4 Computer Program / Software

STAAD.Pro software is used for structural analysis. Microsoft Excel Spreadsheet is used for load calculations and designs.

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2.0 MATERIALS

4.1 Cement

Portland slag cement conforming to IS 455 shall be used for piling work. Ordinary Portland Cement of Grade-43 conforming to IS: 8112 for other RCC works

4.2 Reinforcement Steel

Reinforced Steel High Yield Strength TMT deformed steel bars of grade Fe-500 D bars conforming to IS: 1786

4.3 Concrete

M35 Grade concrete for all liquid retaining structures shall be considered

3.0 DESIGN DATA AND STRUCTURE DESCRIPTION

The bearing capacity recommendations shall be per the soil investigation report

4.0 DESCRIPTION OF STRUCTURES AND DESIGN METHODOLOGY

4.1 Design Methodology

1. The Tank structure and inside pit has been modeled using plate elements and analyzed using STAAD Pro for the loads and load combinations. Maximum plate stresses are considered for vertical and horizontal direction for moment and shear values.
2. The Dead load, Live load etc. that come on to the structure are calculated manually using spread sheet taking values from the Specification document and corresponding Codal provisions.
3. The calculated loads are then applied on the model and the analysis has been carried out using Staad.Pro
4. The analysis and design is done in STAAD.Pro software.
5. The resultant support reactions and moment values are extracted from the Staad.Pro results and the super structure is designed using Spread sheet by Limit State Method of design.

5.0 BASIC LOADS AND LOAD COMBINATION

The following basic load cases and load combinations are considered.

Basic Loads

1	DL	Dead Load
2	BL	BUOYANCY LOAD (BL)
3	H	EARTH PRESSURE (H) (DRY DENSITY)
4	LL	LIVE LOAD
5	F1	HYDROSTATIC WATER PRESSURE INSIDE (F1)
6	F2	SURCHARGE (F2)
7	F3	SUBMERGED SOIL (F3)
8	TL	THERMAL LOAD

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*****Service load combination*****

LOAD COMB 100 1.0DL

1 1.0

LOAD COMB 101 1.0DL+1.0DRYEARTH PRESSURE(H)

1 1.0 3 1.0

LOAD COMB 102 1.0DL+1.0DRYEARTH PRESSURE(H)+1.0INSIDEWATET PRESSURE(F1)

1 1.0 3 1.0 4 1.0

LOAD COMB 103 1.0DL+1.0UPLIFT(BL)

1 1.0 2 1.0

LOAD COMB 104 1.0DL+1.0SUBMERGEDSOIL(F3)

1 1.0 6 1.0

LOAD COMB 105 1.0DL+1.0EARTH PRESSURE+1.0SURCHARGE(F2)

1 1.0 3 1.0 5 1.0

LOAD COMB 106 1.0DL+1.0LL

1 1.0 7 1.0

LOAD COMB 107 1.0DL+1.0DRYEARTH PRESSURE(H)+1.0LL

1 1.0 3 1.0 7 1.0

LOAD COMB 108 1.0DL+1.0DRYEARTH PRESSURE(H)+1.0INSIDEWATET PRESSURE(F1)+1.0LL

1 1.0 3 1.0 4 1.0 7 1.0

LOAD COMB 109 1.0DL+1.0SUBMERGEDSOIL(F3)+1.0LL

1 1.0 6 1.0 7 1.0

LOAD COMB 110 1.0DL+1.0EARTH PRESSURE+SURCHARGE(F2)+1.0LL

1 1.0 3 1.0 5 1.0 7 1.0

LOAD COMB 111

1.0DL+1.0DRYEARTH PRESSURE(H)+1.0INSIDEWATET PRESSURE(F1)+0.8LL+.8EL(+)XDIR+0.8

HYDR0DYN(+)XDIR

1 1.0 3 1.0 4 1.0 7 0.8 12 0.8 10 0.8

LOAD COMB 112 1.0DL+DRYEARTH PRESSURE(H)+1.0INSIDEWATET PRESSURE(F1)+0.8LL

1 1.0 3 1.0 4 1.0 7 0.8

LOAD COMB 113 1.0DL+1.0SUBMERGEDSOIL(F3)+0.8LL

1 1.0 6 1.0 7 0.8

LOAD COMB 114 1.0DL+1.0EARTH PRESSURE+1.0SURCHARGE(F2)+0.8LL

1 1.0 3 1.0 5 1.0 7 0.8

LOAD COMB 115

1.0DL+1.0DRYEARTH PRESSURE(H)+1.0INSIDEWATET PRESSURE(F1)+0.8LL+.8EL(+)ZDIR+0.8

HYDR0DYN(+)ZDIR

1 1.0 3 1.0 4 1.0 7 0.8 13 0.8 11 0.8

LOAD COMB 116

1.0DL+1.0DRYEARTH PRESSURE(H)+1.0INSIDEWATET PRESSURE(F1)+0.8LL+.8EL(-

)XDIR+0.8HYDR0DYN(-)XDIR

1 1.0 3 1.0 4 1.0 7 0.8 14 0.8 10 -0.8

LOAD COMB 117

1.0DL+1.0DRYEARTH PRESSURE(H)+1.0INSIDEWATET PRESSURE(F1)+0.8LL+.8EL(-

)ZDIR+0.8HYDR0DYN(-)ZDIR

1 1.0 3 1.0 4 1.0 7 0.8 15 0.8 11 -0.8

LOAD COMB 118

1.0DL+1.0DRYEARTH PRESSURE(H)+1.0INSIDEWATET PRESSURE(F1)+1.0LL+1.0SURCHARGE(

F2)

1 1.0 3 1.0 4 1.0 7 1.0 5 1.0

*****STRENGTH LOAD COMBINATION

LOAD COMB 201 1.5DL+1.5DRYEARTH PRESSURE(H)

1 1.5 3 1.5

LOAD COMB 202 1.5DL+1.5DRYEARTH PRESSURE(H)+1.5INSIDEWATET PRESSURE(F1)

1 1.5 3 1.5 4 1.5

LOAD COMB 203 1.5DL+1.5UPLIFT(BL)

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1 1.5 2 1.5
LOAD COMB 204 1.5DL+1.5SUBMERGEDSOIL(F3)
1 1.5 6 1.5
LOAD COMB 205 1.5DL+1.5EARTH PRESSURE+1.5SURCHARGE(F2)
1 1.5 3 1.5 5 1.5
LOAD COMB 206 1.5DL+1.5LL
1 1.5 7 1.5
LOAD COMB 207 1.5DL+1.5DRYEARTH PRESSURE(H)+1.5LL
1 1.0 3 1.5 3 1.5 7 1.5
LOAD COMB 208 1.2DL+1.2DRYEARTH PRESSURE(H)+1.2INSIDEWATET PRESSURE(F1)+1.2LL
1 1.2 3 1.2 4 1.2 7 1.2
LOAD COMB 209 1.2DL+1.2SUBMERGEDSOIL(F3)+1.2LL
1 1.2 6 1.2 7 1.2
LOAD COMB 210 1.2DL+1.2EARTH PRESSURE+1.2SURCHARGE(F2)+1.2LL
1 1.2 3 1.2 5 1.2 7 1.2
LOAD COMB 211 1.5DL+1.5DRYEARTH PRESSURE(H)+1.5INSIDEWATET PRESSURE(F1)+1.5TL
1 1.5 3 1.5 4 1.5
LOAD COMB 212
1.5DL+1.5DRYEARTH PRESSURE(H)+1.5INSIDEWATET PRESSURE(F1)+1.5LL+1.5TL+
1 1.5 3 1.5 4 1.5 7 1.5 8 1.5
LOAD COMB 213
1.5DL+1.5DRYEARTH PRESSURE(H)+1.5INSIDEWATET PRESSURE(F1)+1.5LL+1.5TL-
1 1.5 3 1.5 4 1.5 7 1.5 9 1.5
*****HYDRODYNAMIC COMBINATION
LOAD COMB 214
1.2DL+1.2DRYEARTH PRESSURE(H)+1.2INSIDEWATET PRESSURE(F1)+1.2LL+1.2EL(+)XDIR+1.2
HYDR0DYN(+)XDIR
1 1.2 3 1.2 4 1.2 7 1.2 10 1.2 12 1.2
LOAD COMB 215
1.2DL+1.2DRYEARTH PRESSURE(H)+1.2INSIDEWATET PRESSURE(F1)+1.2LL+1.2EL(+)ZDIR+1.2
HYDR0DYN(+)ZDIR
1 1.2 3 1.2 4 1.2 7 1.2 11 1.2 13 1.2
LOAD COMB 216
1.2DL+1.2DRYEARTH PRESSURE(H)+1.2INSIDEWATET PRESSURE(F1)+1.2LL+1.2EL(-
)XDIR+1.2HYDR0DYN(-)XDIR
1 1.2 3 1.2 4 1.2 7 1.2 10 -1.2 14 1.2
LOAD COMB 217
1.2DL+1.2DRYEARTH PRESSURE(H)+1.2INSIDEWATET PRESSURE(F1)+1.2LL+1.2EL(-
)ZDIR+1.2HYDR0DYN(-)ZDIR
1 1.2 3 1.2 4 1.2 7 1.2 11 -1.2 15 1.2

LOAD COMB 218
1.5DL+1.5DRYEARTH PRESSURE(H)+1.5INSIDEWATET PRESSURE(F1)+1.5EL(+)XDIR+1.5YDR0
DYN(+)XDIR
1 1.5 3 1.5 4 1.5 10 1.5 12 1.5
LOAD COMB 219
1.5DL+1.5DRYEARTH PRESSURE(H)+1.5INSIDEWATET PRESSURE(F1)+1.5EL(+)ZDIR+1.5YDR0
DYN(+)ZDIR
1 1.5 3 1.5 4 1.5 11 1.5 13 1.5
LOAD COMB 220
1.5DL+1.5DRYEARTH PRESSURE(H)+1.5INSIDEWATET PRESSURE(F1)+1.5EL(-
)XDIR+1.5YDR0DYN(-)XDIR
1 1.5 3 1.5 4 1.2 10 -1.5 14 1.5
LOAD COMB 221
1.5DL+1.5DRYEARTH PRESSURE(H)+1.5INSIDEWATET PRESSURE(F1)+1.5EL(-
)ZDIR+1.5YDR0DYN(-)ZDIR
1 1.5 3 1.5 4 1.5 11 -1.5 15 1.5

Annexure A – Primary Loads

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Dead load

Selfweight applied by using staad inbuild application command SELFWEIGHT Y "1"

Walls & raft are subjected to water and earth pressure.

Data:

Soil density	=	18	kN/m ³	
Angle of internal friction for soil	=	45	degrees	
Coeff of earth pressure at rest = $1 - \sin \phi$	=	0.3		
Density of water	=	10	kN/m ³	
Density of concrete	=	25	kN/m ³	
Surcharge Live load	=	20	kN/m ²	(for heavy vehicle load)
Submerged Soil load	=	8	kN/m ³	
Compressive strength	=	35	N/mm ²	
Yield strength of rebar	=	500	N/mm ²	
Allowable bearing pressure (net)	=	80	kN/m ²	

BUOYANCY LOAD (BL) UPLIFT PRESSURE (GROUND WATER)

Considered Depth below ground level	=	1.0	m	
Uplift pressure @ +0.25m lvl	=	10	kN/m ²	
Considered Depth below ground level	=	5.4	m	
Uplift pressure @ +0.25m lvl	=	54x	kN/m ²	

EARTH PRESSURE (DRY DENSITY)

Depth of dry soil (from F.G.L)	=	6.0	m	
Earth pressure due to dry soil $(1/3) \times 6 \times 18$	=	36	kN/m ²	

WATER PRESSURE (INSIDE TANK)

Water depth inside	=	6	m	
Water pressure from tank inside = 5.4×10	=	54	kN/m ²	

SURCHARGE PRESSURE

Surcharge Live load	=	20	kN/m ² (For Heavy vehicle load)	
Surcharge soil pressure = $0.333 \times 6.0 \times 20$	=	40	kN/m ²	

SUBMERGED SOIL PRESSURE

soil depth (Consider from F.G.L)	=	6.0	m	
Submerged soil pressure = $0.333 \times 6.0 \times 8$	=	16	kN/m ²	

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Piping Load

N5 600NB Pipe load with content

Dead weight of Pipe $350\text{kg/m} = 0.35 \times 1.5\text{m} = (0.525 \text{ kN})$

$(\pi \times 600^2 / 4 \times 10\text{kN/m}^3 \times 1.5\text{m}) = (4.24 + 0.525) = 4.8 \text{ kN}$

Weight of pedestal $(0.3 \times 0.3 \times 2 \times 25) = 0.45 \text{ kN}$

Total applied load = 5.5kN

Earthquake Load

Design Horizontal seismic coefficient

For Impulsive Mode

Zone factor for Zone V

Importance Factor

Response Reduction Factor

Damping

$$A_{hi} = (Z/2)(I/R)(S_a/g)^i$$

$$Z = 0.24$$

$$I = 1.5$$

$$R = 2.5 \text{ tank with fixed base}$$

$$= 5 \%$$

Applied in walls by using staad inbuilt option and by using staad definition method.

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HYDRO DYNAMIC LOAD

LONGITUDINAL (X) DIRECTION

Shape of Tank	=	Rectangular
Length of Tank	=	4.0 m
Width of Tank	=	4.0 m
Wall thickness (above base Slab)	=	400 mm
Level at of top of tank	=	6 m
Water level	=	6 m
Total height of wall	=	6 m
Thickness of top slab	=	200 mm
Maximum thickness of wall considered	=	400 mm
Thickness of wall	=	400 mm
Base slab thickness	=	400 mm
Height of water	=	6 m
Average height of water above Base slab	h =	6 m
Unit weight of concrete	=	25 kN/m ³
Unit weight of water	=	10 kN/m ³
Unit weight of Brick	=	19 kN/m ³
Grade of concrete	=	35
Free Board provided	=	0 m

Calculation of weight of various parts of tank

Sl.No	Element	Length	avg H	Thk	No	vol.	weight
		m	m	m	no	m ³	kN
1	0.4m thick walls	4.0	6	0.4	4	38.4	960.0
2	Base slab	4.0	4	0.4	1	6.4	160.0
3	Top slab	4.0	4.0	0.4	1	6.4	160.0
4	Frame load					0	25.0
5	Pipe loads	15.0	0.600dia	350kg/m	4	-	5.3
6	Water	4.0	4.0		6	96	960.0

Weight of empty tank	=	1310.3 kN
Mass of empty Tank	ms =	133563 kg

Spring Mass Model Parameters

Weight of water	=	960.0 kN	(Refer
Volume of water	=	96 m ³	Section 4.2.1.2
Mass of water	=	97859.3 kg	IITK-GSDMA
height / length	h/L =	1.5	guidelines)
mi/m	=	0.902	
mi	=	88269.1 kg	
mc/m	=	0.176	
mc	=	17223.2 kg	
Note:	90.2	% of water is exited in impulsive mode	
and	17.6	% of water is exited in convective mode	
hi/h	=	0.44	
hi	=	2.64 m	
hc/h	=	0.79	
hc	=	4.76 m	

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Time Period

$$\text{Time Period of Impulsive mode} \quad T_i = 2 * \pi * I * \sqrt{(d/g)}$$

where d = deflection of tank wall at height h- when loaded by uniform pressure q where

$$\begin{aligned} \frac{((m_i/2) * h_i) + (m_w * (h/2))}{((m_i/2) + m_w)} &= h \\ m_w &= \text{mass of one wall (inner dimension)} \\ &= 24465 \text{ kg} \\ h &= \frac{(((88269.1131498471/2) * 2.64) + 24464.832 * (6/2))}{((88269.1131498471/2) + 24464.832)} \\ &= 2.77 \text{ m} \\ q &= \frac{(m_i/2 + m_w) * g}{Bh} \\ &= 28040.00 \text{ N/m}^2 \\ &= 28.04 \text{ kN/m}^2 \end{aligned}$$

Deflection of wall, considering a strip of unit width of wall as cantilever and subjected to a concentrated force $P = q \times h \times 1.0$

$$\begin{aligned} \text{Deflection of cantilever section} &= \frac{P(\bar{h})^3}{3EI} \\ P &= qh \times 1 \\ &= 168.2400005 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Moment of Inertia} \quad I &= \frac{1 * t^3}{12} \\ &= 0.005333333 \text{ m}^4 \end{aligned}$$

$$\begin{aligned} \text{Young's Modulus (E)} &= 5000 * \sqrt{f_{ck}} \\ &= 29580.39892 \text{ N/mm}^2 \\ &= 29580398.92 \text{ kN/m}^2 \end{aligned}$$

$$\begin{aligned} \text{Deflection of cantilever section (Max-d)} &= \frac{W \times h^3}{3EI} \\ &= 0.007555176 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{Time Period of Impulsive mode} \quad T_i &= 2 * \pi * I * \sqrt{(d/g)} \\ &= 0.174 \text{ sec} \end{aligned}$$

$$\text{Time Period of Convective mode} \quad T_c = C_c * \sqrt{L/r}$$

$$\begin{aligned} h/L &= 1.5 \\ C_c &= 4.5 \text{ From Fig 7} \end{aligned}$$

$$T_c = 2.873 \text{ sec}$$

Design Horizontal seismic coefficient

For Impulsive Mode

$$\begin{aligned} A_{hi} &= \frac{(Z/2)(I/R)(S_a/g)_i}{Z} \\ \text{Zone factor for Zone V} \quad Z &= 0.24 \\ \text{Importance Factor} \quad I &= 1.5 \\ \text{Response Reduction Factor} \quad R &= 2.5 \text{ tank with fixed base} \\ \text{Damping} &= 5 \% \\ T_i &= 0.174 \text{ sec} \end{aligned}$$

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Table 1

S.No	Time Period (Sec)	Damping Factor (as a % of critical damping)		
		5%	2%	0.5%
1	0.00	1.000	1.400	1.75
2	0.05	1.750	2.450	3.0625
3	0.10	2.500	3.500	4.375
4	0.20	2.500	3.500	4.375
5	0.30	2.500	3.500	4.375
6	0.40	2.500	3.500	4.375
7	0.45	2.222	3.111	3.88889
8	0.50	2.000	2.800	3.5
9	0.55	1.818	2.545	3.18182
10	0.75	1.333	1.867	2.33333
11	0.95	1.053	1.474	1.84211
12	1.15	0.870	1.217	1.52174
13	1.35	0.741	1.037	1.2963
14	1.55	0.645	0.903	1.12903
15	1.75	0.571	0.800	1
16	1.95	0.513	0.718	0.89744
17	2.15	0.465	0.651	0.81395
18	2.35	0.426	0.596	0.74468
19	2.55	0.392	0.549	0.68627
20	2.75	0.364	0.509	0.63636
21	2.95	0.339	0.475	0.59322
22	3.15	0.317	0.444	0.55556
23	3.35	0.299	0.418	0.52239
24	3.55	0.282	0.394	0.49296
25	3.75	0.267	0.373	0.46667
26	3.95	0.253	0.354	0.44304
27	4.15	0.241	0.337	0.42169
28	4.35	0.230	0.322	0.4023
29	4.55	0.220	0.308	0.38462
30	4.75	0.211	0.295	0.36842
31	4.95	0.202	0.283	0.35354
32	5.15	0.194	0.272	0.33981
33	5.35	0.187	0.262	0.3271
34	5.55	0.180	0.252	0.31532
35	5.75	0.174	0.243	0.30435
36	5.95	0.168	0.235	0.29412

(In Units of 'g')

Sa/g from IS 1893 - part 1 -2002 Fig 2

$$= 3.61$$

Therefore

For Convective Mode

Tc

Sa/g from IS 1893 - part 1 -2002 Fig 2

Therefore

$$\begin{aligned} A_{hi} &= 0.26 \\ A_{hc} &= (Z/2)(I/R)(S_a/g)_c \\ &= 2.873 \text{ sec} \\ &= 0.45 \\ A_{hc} &= 0.033 \end{aligned}$$

Base Shear

Base shear in impulsive mode

$$\begin{aligned} V_i &= (A_{hi}) * (m_i + m_w + m_t)g \\ &= 287539 \text{ N} \\ &= 287.539 \text{ kN} \end{aligned}$$

Base shear in Convective mode

$$\begin{aligned} V_c &= (A_{hc}) * m_c * g \\ &= 5575.68 \text{ N} \\ &= 5.58 \text{ kN} \end{aligned}$$

Total Base Shear
at the bottom of wall

$$\begin{aligned} V &= \text{sqrt}(V_i^2 + V_c^2) \\ &= 287.593 \text{ kN} \end{aligned}$$

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This acts at the centre of gravity of the tank.

Total seismic weight of the tank	=	2270.3	kN
% of base shear	=	12.668	%

Hydrodynamic pressure on wall

(Clause 4.9.1)

Impulsive Hydrodynamic Pressure

$$p_{iw} = Q_{iw}(y) (A_h)_i r g h$$

Lateral hydrodynamic impulsive pressure on wall where

ρ = mass density of liquid
 f = circumferential angle
 y = vertical dist. of point on tank wall from bottom of wall

y/H (at base of wall)

$$Q_{iw}(y) = 0.866 * (1 - (y/h)^2) * \tanh(0.866 L/h)$$

$Q_{iw}(y=0)$

$$Q_{iw}(y) = 0.866 * (1 - 0) * \tanh(0.866 * 4/6)$$

$$= 0.451$$

$$(A_h)_i = 0.26$$

$$\rho = 1000 \text{ kg/m}^3$$

$$g = 9.81 \text{ m/sec}^2$$

$$h = 6.000$$

Impulsive hydrodynamic pressure at the base of wall

$$p_{iw} = 0.451 * 0.26 * 1000 * 9.81 * 6$$

$$= 6901.92 \text{ N/m}^2$$

$$= 6.9 \text{ kN/m}^2$$

Convective Hydrodynamic Pressure

$$p_{cw} = Q_{cw}(y) * (A_h)_c * r * g * L$$

Convective Hydrodynamic Pressure on wall

$$Q_{cw}(y) = 0.4165 * \cos h(3.162 y/L) / \cosh(3.162 h/L)$$

At base of wall

$$y = 0$$

$$Q_{cw}(y) = 0.4165 * \cosh(0) / \cosh(3.162 * 6/4)$$

$$= 0.007$$

$$(A_h)_c = 0.033$$

$$p_{cw} = 0.007 * 0.033 * 1000 * 9.81 * 4$$

$$= 9.06444 \text{ N/m}^2$$

$$= 0.009 \text{ kN/m}^2$$

Convective Hydrodynamic pressure at the base of wall ($y=0$)

Equivalent Linear Pressure Distribution

Impulsive Hydrodynamic pressure

Base Shear due to Impulsive liquid mass

$$q_i = \frac{(A_h)_i * m_i * g}{2B}$$

$$= \frac{0.26 * 88269.1131498471 * 9.81}{2 * 1000 * 4}$$

$$= 28.15 \text{ kN/m}$$

Value of linearised pressure

Bottom

Top

$$a_i = \frac{q_i * (4h - 6h_i)}{h^2}$$

$$b_i = \frac{q_i * (6h_i - 2h)}{h^2}$$

$$= \frac{28.15 * (4 * 6 - 6 * 2.64)}{6^2}$$

$$= \frac{28.15 * (6 * 2.64 - 4 * 6)}{6^2}$$

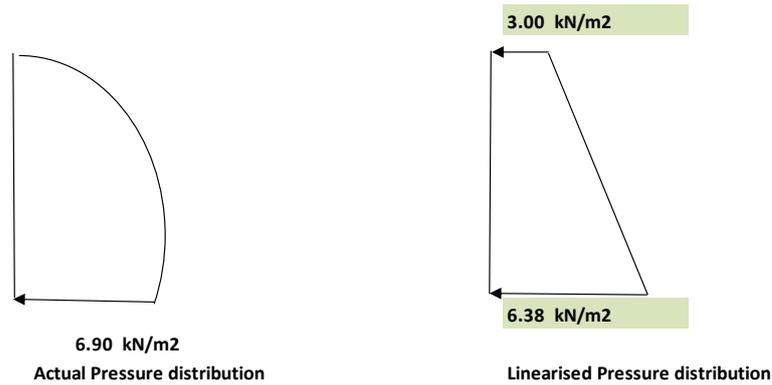
$$= 6.38 \text{ kN/m}^2$$

$$= 3.00 \text{ kN/m}^2$$

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Convective Hydrodynamic pressure

Base Shear due to Impulsive liquid mass

$$q_c = \frac{(A_h)_c * m_c * g}{2B}$$

$$= \frac{0.033 \times 17223.2415902141 \times 9.8}{2 \times 1000 \times 4}$$

$$= 0.70 \text{ kN/m}$$

Value of linearised pressure

Bottom

$$a_c = \frac{q_c * (4h - 6h_c)}{h^2}$$

$$= \frac{0.7 \times (4 \times 6 - 6 \times 4.76)}{6^2}$$

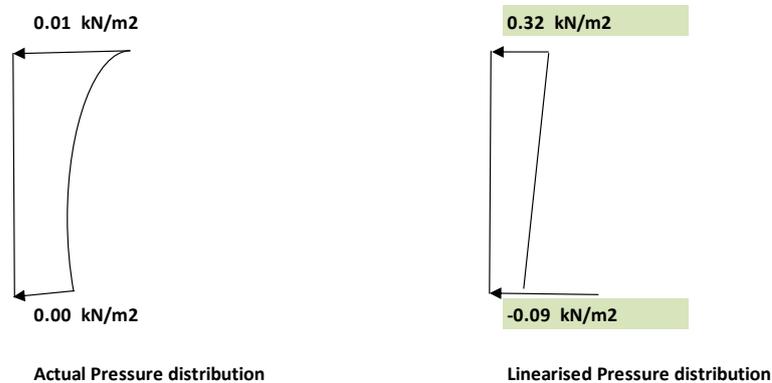
$$= -0.09 \text{ kN/m}^2$$

Top

$$b_c = \frac{q_c * (6h_c - 2h)}{h^2}$$

$$= \frac{0.7 \times (6 \times 4.76 - 2 \times 6)}{6^2}$$

$$= 0.32 \text{ kN/m}^2$$



Sloshing Wave Height

Maximum Sloshing Wave Height

Response Reduction Factor

Free Board provided

Free Board provided is less than the sloshing height

$$d_{max} = (A_h)_c * R * L/2$$

$$(A_h)_c = 0.033$$

$$R = 2.5$$

$$L = 4.00 \text{ m}$$

$$d_{max} = 0.17 \text{ m}$$

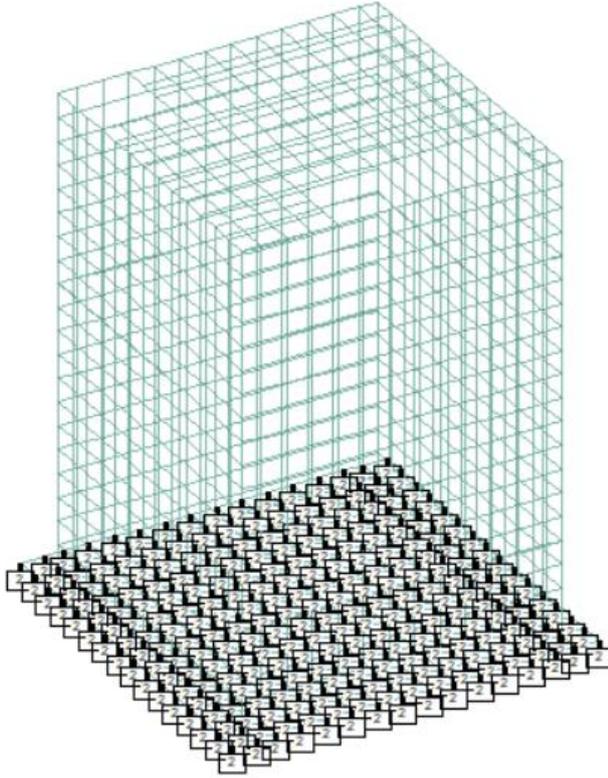
$$= 0 \text{ m}$$

Annexure B STAAD Model

Analysis and Design of Sump Pit

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Engineering Concepts

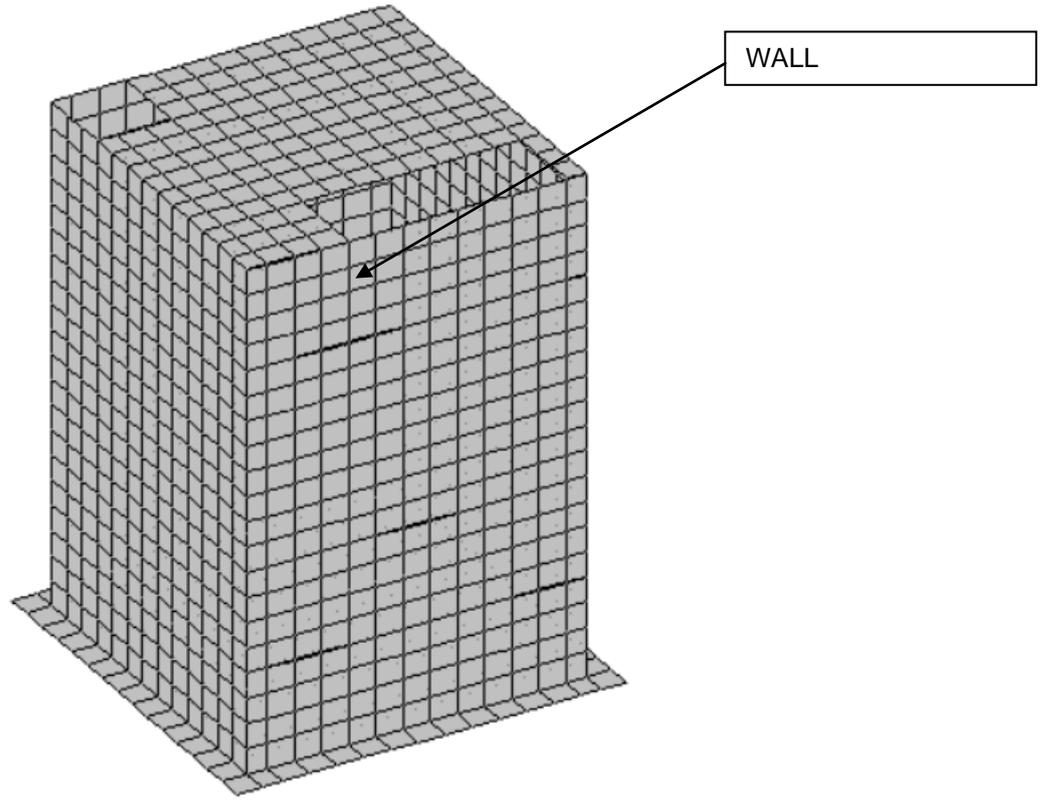


3D ISO VIEW OF STAAD MODEL DRAIN PIT

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DRAIN PIT WALL

Annexure B.1 STAAD Input

Annexure C

Design of Tank Base Slab

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CHECK FOR SAFE BEARING PRESSURE

SBC	=	314 kN/m ²
Inc Factor fo BC	=	1
Depth of Foundation below NGL	=	1.5 m
Depth of Raft	=	0.5 m
Net SBC	=	314 kN/m ²

Summary of Base Pressure from STAAD:

			Horizontal	Vertical	Horizontal
	Node	L/C	Fx N/mm2	Fy N/mm2	Fz N/mm2
Max Px	1	100 1.0DL	0	0.069	0
Min Px	1	100 1.0DL	0	0.069	0
Max Py	1410	115 1.0DL+1.0DRYEARTH-PRESSURE(H)+1.0INSID	0	0.232	0
Min Py	15	103 1.0DL+1.0UPLIFT(BL)	0	0.002	0
Max Pz	1	100 1.0DL	0	0.069	0
Min Pz	1	100 1.0DL	0	0.069	0

MAX	232 kN/m²	<	Net SBC	314 kN/m²
MIN	2 kN/m²	>	Safe	0 kN/m²
			No Tension	

Support Condition

As per Soil Report subgrade modulus – 25500 kN/m²/m

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DESIGN OF COMBINED FOUNDATION Tank Foundation

Refer STAAD File :

SUMMARY OF FORCES FROM STAAD : RAFT SLAB DESIGN

	Plate	L/C	Shear		Membrane		Bending Moment			
			SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Mx kNm/m	My kNm/m	Mxy kNm/m
Max Qx	944	205 1.5DL+1.5EARTHPRESSURE	0.502	0.003	0	0	0	75.42	8.441	-1.391
Min Qx	283	220 1.5DL+1.5DRYEARTHPRES	-0.469	-0.011	0	0	0	42.168	0.717	-5.006
Max Qy	617	205 1.5DL+1.5EARTHPRESSURE	0.013	0.497	0	0	0	7.499	71.669	-0.598
Min Qy	618	205 1.5DL+1.5EARTHPRESSURE	0.001	-0.417	0	0	0	7.266	67.658	0.548
Max Sx	1265	201 1.5DL+1.5DRYEARTHPRES	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Min Sx	1265	201 1.5DL+1.5DRYEARTHPRES	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Max Sy	1265	201 1.5DL+1.5DRYEARTHPRES	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Min Sy	1265	201 1.5DL+1.5DRYEARTHPRES	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Max Sxy	1265	201 1.5DL+1.5DRYEARTHPRES	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Min Sxy	1265	201 1.5DL+1.5DRYEARTHPRES	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Max Mx	944	205 1.5DL+1.5EARTHPRESSURE	0.502	0.003	0	0	0	75.42	8.441	-1.391
Min Mx	611	206 1.5DL+1.5LL	-0.009	-0.02	0	0	0	-57.137	-57.363	-0.078
Max My	617	205 1.5DL+1.5EARTHPRESSURE	0.013	0.497	0	0	0	7.499	71.669	-0.598
Min My	612	206 1.5DL+1.5LL	-0.009	0.03	0	0	0	-56.078	-57.732	-0.279
Max Mxy	891	206 1.5DL+1.5LL	0.085	0.063	0	0	0	1.667	-1.32	27.961
Min Mxy	396	206 1.5DL+1.5LL	-0.04	0.166	0	0	0	-7.523	-1.613	-27.593

DESIGN FOR BENDING

Maximum positive bending Moment in X direction

$$\begin{aligned} M_x &= 75 \text{ kNm} \\ M_{xy} &= -1 \text{ kNm} \\ M_{xx} &= \text{ABS}(M_x) + \text{ABS}(M_{xy}) \\ M_{xx} &= 77 \text{ kNm} \end{aligned}$$

Plate No	Load case
0	

Maximum negative bending Moment in X direction

$$\begin{aligned} M_x &= -57 \text{ kNm} \\ M_{xy} &= 0 \text{ kNm} \\ M_{xx} &= \text{ABS}(M_x) + \text{ABS}(M_{xy}) \\ M_{xx} &= 57 \text{ kNm} \end{aligned}$$

Plate No	Load case
0	

Maximum positive bending Moment in Y direction

$$\begin{aligned} M_y &= 72 \text{ kNm} \\ M_{xy} &= -1 \text{ kNm} \\ M_{yy} &= \text{ABS}(M_y) + \text{ABS}(M_{xy}) \\ M_{yy} &= 72 \text{ kNm} \end{aligned}$$

Plate No	Load case
0	

Maximum negative bending Moment in Y direction

$$\begin{aligned} M_y &= -58 \text{ kNm} \\ M_{xy} &= 0 \text{ kNm} \\ M_{yy} &= \text{ABS}(M_y) + \text{ABS}(M_{xy}) \\ M_{yy} &= 58 \text{ kNm} \end{aligned}$$

Plate No	Load case
0	

Material:

Concrete grade 35 N/mm²

Steel grade 500 N/mm²

Cover:

Clear cover Bottom 75 mm Top 50 mm

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DESIGN FOR BENDING		
(a) Depth required for bending		
Maximum factored moment	$M_u/f_c k b d^2$	= 0.133
	M_u	= Max of (M_{xx} , M_{yy}) 76.8 kNm
	d_{reqd}	= $\sqrt{M_u/(0.133 \cdot f_c k \cdot b)}$ 128.5 mm
	D_{reqd}	= 211 mm
	D_{prov}	= 400 mm
(b) Bottom reinforcement in X- Dir		
Max. factored moment	M_u	= 77 kNm/m
Effective depth in X-dir	d	= 301 mm
	M_u/bd^2	= 0.848
% of tension reinf. required	ρ_t	= 0.201 %
Min. % of tension reinf	$\rho_{t, min}$	= 0.170 %
Area of tension steel required	$A_{st reqd}$	= 604 mm ²
Dia of reinf.		= 16 mm
Spacing of bar required	S_{reqd}	= 333
	Provide	16 @ 150 mm C/C
% of tension reinf. Provided	$\rho_{t, prov}$	= 0.445 %
(c) Top reinforcement in X- Dir		
Max. factored moment	M_u	= 57 kNm/m
Effective depth in X-dir	d	= 326 mm
	M_u/bd^2	= 0.538
% of tension reinf. required	ρ_t	= 0.126 %
Min. % of tension reinf	$\rho_{t, min}$	= 0.170 %
Area of tension steel required	$A_{st reqd}$	= 554 mm ²
Dia of reinf.		= 16 mm
Spacing of bar required	S_{reqd}	= 363
	Provide	16 @ 150 mm C/C
% of tension reinf. Provided	$\rho_{t, prov}$	= 0.411 %
(d) Bottom reinforcement in Y- Dir		
Max. factored moment	M_u	= 72 kNm/m
Effective depth in Y-dir	d	= 317 mm
	M_u/bd^2	= 0.719
% of tension reinf. required	ρ_t	= 0.170 %
Min. % of tension reinf	$\rho_{t, min}$	= 0.170 %
Area of tension steel required	$A_{st reqd}$	= 539 mm ²
Dia of reinf.		= 16 mm
Spacing of bar required	S_{reqd}	= 373
	Provide	16 @ 150 mm C/C
% of tension reinf. Provided	$\rho_{t, prov}$	= 0.423 %
(e) Top reinforcement in Y- Dir		
Max. factored moment	M_u	= 58 kNm/m
Effective depth in Y-dir	d	= 342 mm
	M_u/bd^2	= 0.494
% of tension reinf. required	ρ_t	= 0.115 %
Min. % of tension reinf	$\rho_{t, min}$	= 0.170 %
Area of tension steel required	$A_{st reqd}$	= 581 mm ²
Dia of reinf.		= 16 mm
Spacing of bar required	S_{reqd}	= 346
	Provide	16 @ 150 mm C/C
% of tension reinf. Provided	$\rho_{t, prov}$	= 0.392 %

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CHECK FOR ONE WAY SHEAR

$$F_y = 500 \text{ N/mm}^2$$

SUMMARY OF FORCES FROM STAAD : SQX Considered shear

Maximum shear stress from D distance from face of column to edge of the footing

$$T_v = \text{AVG SQx} = 0.380 \text{ N/mm}^2$$

$$\text{Concrete shear stress } T_c = 0.479 \text{ N/mm}^2 \quad T_v < T_c \text{ Safe}$$

SUMMARY OF FORCES FROM STAAD : SAY Considered shear

Maximum shear stress from D distance from face of column to edge of the footing

$$T_v = \text{Max SQY} = 0.380 \text{ N/mm}^2$$

$$\text{Concrete shear stress } T_c = 0.468 \text{ N/mm}^2 \quad T_v < T_c \text{ Safe}$$

$$A_{sv}/S_v = (T_v - T_c) * 1000 / (0.87 * f_y)$$

CHECK FOR PUNCHING SHEAR

SUMMARY OF FORCES FROM STAAD : (STAAD GROUP TWOWAY SHEAR)

(a) For Column

	Plate	L/C	Shear		Membrane			Bending Moment		
			SQX (local)	SQY (local)	SX (local)	SY (local)	SXY (local)	Mx kNm/m	My kNm	Mxy kNm
Max Qx	944	205 1.5DL+1.5EARTH PRESSURE	0.502	0.003	0	0	0	75.42	8.441	-1.391
Min Qx	283	220 1.5DL+1.5DRYEARTH PRESSURE	-0.469	-0.011	0	0	0	42.168	0.717	-5.006
Max Qy	617	205 1.5DL+1.5EARTH PRESSURE	0.013	0.497	0	0	0	7.499	71.669	-0.598
Min Qy	618	205 1.5DL+1.5EARTH PRESSURE	0.001	-0.417	0	0	0	7.266	67.658	0.548
Max Sx	1265	201 1.5DL+1.5DRYEARTH PRESSURE	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Min Sx	1265	201 1.5DL+1.5DRYEARTH PRESSURE	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Max Sy	1265	201 1.5DL+1.5DRYEARTH PRESSURE	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Min Sy	1265	201 1.5DL+1.5DRYEARTH PRESSURE	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Max Sxy	1265	201 1.5DL+1.5DRYEARTH PRESSURE	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Min Sxy	1265	201 1.5DL+1.5DRYEARTH PRESSURE	0.011	0.008	0	0	0	-2.078	-1.965	2.108
Max Mx	944	205 1.5DL+1.5EARTH PRESSURE	0.502	0.003	0	0	0	75.42	8.441	-1.391
Min Mx	611	206 1.5DL+1.5LL	-0.009	-0.02	0	0	0	-57.137	-57.363	-0.078
Max My	617	205 1.5DL+1.5EARTH PRESSURE	0.013	0.497	0	0	0	7.499	71.669	-0.598
Min My	612	206 1.5DL+1.5LL	-0.009	0.03	0	0	0	-56.078	-57.732	-0.279
Max Mxy	891	206 1.5DL+1.5LL	0.085	0.063	0	0	0	1.667	-1.32	27.961
Min Mxy	396	206 1.5DL+1.5LL	-0.04	0.166	0	0	0	-7.523	-1.613	-27.593

Punching shear stress from d/2 distance from the periphery of the pedestal to D distance

$$T_p = \text{Max SQx, Sqy} = 0.47 \text{ N/mm}^2$$

Allowable shear stress

$$T_c = 0.25 * f_{ck}^{0.5} = 1.37 \text{ N/mm}^2$$

$$0.47 < 1.37$$

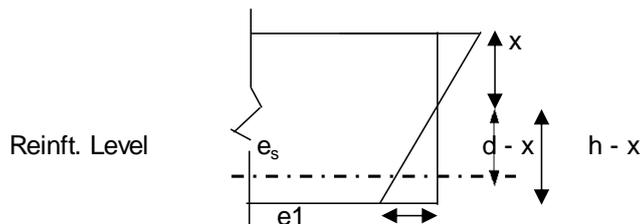
Hence SAFE.

Annexure C1 Base Slab Crack Width Check

Check for Crack width in 400Thk Base Slab:

Thickness of Wall	h	=	500	mm
Clear cover	dc	=	50	mm
Dia of bar used	db	=	25	mm
Effective Depth(d)	d	=	437.5	mm
Spacing of bars	s	=	140	mm
Service bending moment		=	51.21	kN-m
Compressive strength of concrete	f_{ck}	=	35	N/mm ²
Tensile strength of steel	f_y	=	500	N/mm ²
σ_{cbc}		=	12	
Modular ratio, m		=	8.12	
Area of steel provided		=	3506	mm ²
Percentage of steel		=	0.80	%

$$\begin{aligned} \text{Depth of neutral axis 'x'} &= \sqrt{\frac{2 m A_{st} b d + (m A_{st})^2}{b}} - m A_{st} \\ &= \sqrt{\frac{2 \times 8.12 \times 3506 \times 1000 \times 438 + (8.12 \times 3506)^2}{1000}} - 8.12 \times 3506 \\ &= 131.88 \quad \text{mm} \end{aligned}$$



$$\begin{aligned} \text{Moment of resistance of the section} &= A_s \times f_s \times (d - x/3) \\ 5.121\text{E}+07 &= 3506 \times (437.5 - 131.88 / 3) \times f_s \\ &= 1.380\text{E}+06 \times f_s \\ \text{Hence stress in steel, } f_s &= 37.11 \quad \text{N/mm}^2 \end{aligned}$$

As per IS - 456: Annex-F, Strain in steel should not exceed $0.8f_y / E_s$

$$\begin{aligned} 0.8 \times f_y / E_s &= 0.8 \times 500 / 200000 \\ &= 0.002 \end{aligned}$$

$$\begin{aligned} \text{Strain in steel} &= f_s / E_s \\ &= 0.000186 < 0.002 \quad \text{OK} \end{aligned}$$

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$$\begin{aligned}\text{Elastic strain at surface } e_1 &= \frac{f_s \times (h - x)}{E_s \times (d - x)} \\ &= \frac{37.11 \times (500 - 131.88)}{200000 \times (437.5 - 131.88)} \\ &= 0.000224\end{aligned}$$

$$\begin{aligned}\text{Stiffening effect of concrete } e_2 &= \frac{b \cdot (h - x)^2}{600000 \cdot A_s \cdot (d - x)} \\ &= \frac{1000 \times (500 - 131.88)^2}{600000 \times 3506 \times (438 - 131.88)} \\ &= 0.0002108\end{aligned}$$

$$\begin{aligned}e_m &= e_1 - e_2 \\ &= 0.000224 - 0.0002108 \\ &= 0.000013 > 0\end{aligned}$$

Check the crack width

$$\text{Crack width 'W' } = \frac{3 \times e_m \times a_{cr}}{1 + 2 \times (a_{cr} - C_{min}) / (h - x)}$$

$$\begin{aligned}a_{cr} &= \sqrt{s/2^2 + dc^2 - db/2} \\ &= \sqrt{70^2 + 62.5 \cdot 25 / 2} \\ &= 81.34 \text{ mm}\end{aligned}$$

$$\text{Hence 'W' } = \frac{3 \times 0.000013 \times 81.34}{1 + 2 \times (81.34 - 50) / (500 - 131.88)}$$

$$= 0.00 < 0.10$$

Hence the reinforcement is ok

Annexure D

Design of Drain Walls

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SUMMARY OF FORCES FROM STAAD : STAAD GROUP NAME: WALLS

	Plate	L/C	Shear	Membrane			Bending Moment			My kNm/m	Mxy kNm/m
			SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Mx kNm/m			
Max Qx	1695	205 1.5	0.41	0.018	-0.456	-0.208	-0.013	-79.592	-11.054	0.851	
Min Qx	1707	205 1.5	-0.41	0.014	-0.455	-0.318	-0.012	-79.743	-10.946	-0.479	
Max Qy	1350	205 1.5	0.004	0.311	-0.103	-0.475	-0.016	-0.882	33.114	0.303	
Min Qy	1324	205 1.5	-0.001	-0.315	-0.109	-0.519	-0.003	0.731	-34.664	-0.115	
Max Sx	1408	221 1.5	-0.149	0.047	0.191	0.048	0.108	-20.298	1.914	-1.15	
Min Sx	1695	205 1.5	0.41	0.018	-0.456	-0.208	-0.013	-79.592	-11.054	0.851	
Max Sy	1331	218 1.5	-0.133	-0.098	0.154	0.245	0.016	12.396	-5.928	-4.328	
Min Sy	1324	219 1.5	-0.001	-0.044	0.041	-0.699	-0.003	-12.787	-33.258	-0.078	
Max Sxy	1458	221 1.5	-0.083	0.036	0.185	-0.232	0.154	0.179	7.84	-2.112	
Min Sxy	1502	219 1.5	0.079	0.026	0.173	-0.139	-0.161	-1.118	4.534	0.193	
Max Mx	1772	205 1.5	0.407	0.005	-0.453	-0.333	0.011	81.545	11.418	-0.594	
Min Mx	1759	205 1.5	-0.409	-0.004	-0.454	-0.309	-0.013	-81.27	-11.513	0.458	
Max My	1350	206 1.5	0.004	0.099	0.049	-0.537	-0.017	12.064	37.118	0.216	
Min My	1324	206 1.5	-0.001	-0.101	0.043	-0.578	-0.004	-12.232	-38.244	-0.085	
Max Mxy	1424	205 1.5	0.122	-0.033	-0.237	-0.28	-0.122	-2.149	2.708	16.912	
Min Mxy	1432	205 1.5	-0.121	-0.035	-0.234	-0.307	0.102	-2.209	2.586	-17.049	

DESIGN FOR BENDING

VERTICAL DIRECTION

(a) Maximum positive bending Moment in Y direction

$$\begin{aligned}
 M_y &= 37.12 \text{ kNm} \\
 M_{xy} &= 0.22 \text{ kNm} \\
 M_{yy} &= \text{ABS}(M_y) + \text{ABS}(M_{xy}) \\
 \mathbf{M_{yy}} &= \mathbf{37 \text{ kNm}} \\
 \text{Corresponding Axial stress in Y direction} \quad S_y &= 0.000 \text{ N/mm}^2 \\
 S_{xy} &= -0.0170 \text{ N/mm}^2 \\
 S_{yy} &= S_y + \text{Abs}(S_{xy}) \\
 \mathbf{S_{yy}} &= \mathbf{0.02 \text{ N/mm}^2} \\
 \text{Axial Force in Y direction} \quad P &= S_{yy} * b * D \\
 P_{yy} &= \mathbf{7 \text{ kN}}
 \end{aligned}$$

Plate No	Load case
1350	206 1.5DL+1.5L

(b) Maximum negative bending Moment in Y direction

$$\begin{aligned}
 M_y &= -38.24 \text{ kNm} \\
 M_{xy} &= -0.09 \text{ kNm} \\
 M_{yy} &= \text{ABS}(M_y) + \text{ABS}(M_{xy}) \\
 \mathbf{M_{yy}} &= \mathbf{38 \text{ kNm}} \\
 \text{Corresponding Axial stress in Y direction} \quad S_y &= 0.000 \text{ N/mm}^2 \\
 S_{xy} &= -0.0040 \text{ N/mm}^2 \\
 S_{yy} &= S_y + \text{Abs}(S_{xy}) \\
 \mathbf{S_{yy}} &= \mathbf{0.00 \text{ N/mm}^2} \\
 \text{Axial Force in Y direction} \quad P &= S_{yy} * b * D \\
 P_{yy} &= \mathbf{2 \text{ kN}}
 \end{aligned}$$

Plate No	Load case
1324	206 1.5DL+1.5L

(c) Maximum Axial stress in Y direction

$$\begin{aligned}
 S_y &= 0.245 \text{ N/mm}^2 \\
 S_{xy} &= 0.0160 \text{ N/mm}^2 \\
 S_{yy} &= S_y + \text{Abs}(S_{xy}) \\
 \mathbf{S_{yy}} &= \mathbf{0.26 \text{ N/mm}^2} \\
 \text{Axial Force in Y direction} \quad P &= S_{yy} * b * D \\
 P_{yy} &= \mathbf{104 \text{ kN}} \\
 \text{Corresponding bending Moment in Y direction} \\
 M_y &= -6 \text{ kNm} \\
 M_{xy} &= -4.33 \text{ kNm} \\
 M_{yy} &= \text{ABS}(M_y) + \text{ABS}(M_{xy}) \\
 \mathbf{M_{yy}} &= \mathbf{10 \text{ kNm}}
 \end{aligned}$$

Plate No	Load case
1331	218 1.5DL+1.5L

Material:

Concrete grade 35 N/mm²

Steel grade 500 N/mm²

Cover:

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Clear cover 50 mm

DESIGN FOR BENDING AND AXIAL TENSION

Depth required for bending

	$Mu/fckbd^2$	=	0.133
Maximum factored moment	Mu	=	Max of (M_{yy}) 38.3 kNm
	d_{reqd}	=	$\sqrt{Mu/(0.133 \cdot fck \cdot b)}$ 90.7 mm
	D_{reqd}	=	149 mm
	D_{prov}	=	400 mm

(a) VERTICAL Reinforcement Inner face of wall (Y-Dirn-Positive Reinf) - Max. My case

For Bending

Max. factored moment	Mu	=	37 kNm/m
Effective depth in X-dir	d	=	342 mm
	Mu/bd^2	=	0.319
% of reinf. required	ρ_t	=	0.074 %
Area of steel required for bending	$A_{st-B reqd}$	=	254 mm ²

For Tension

Maximum axial Tensile force	P_{xx}	=	7 kN
Area of tension steel required	$A_{st-T reqd}$	=	$(P/2)/0.87f_y$ 8 mm ²
Total area of steel required		=	$A_{st-B} + A_{st-T}$ 262 mm ²

Provide	=	16 mm	@ 150
&	=	0 mm	@ 150 alternately

% of tension reinf. Provided	$\rho_{t, prov}$	=	0.392 %
Min. % of reinf	$\rho_{t, min}$	=	0.200 % (As per IS 456 Cl.No 32.5) both face
	$A_{st Provided}$	=	1340 mm ² safe

(b) VERTICAL Reinforcement in Outer face of wall (Y dirn -Negative reinf)- Max. My case

Max. factored moment	Mu	=	38 kNm/m
Effective depth in X-dir	d	=	342 mm
	Mu/bd^2	=	0.328
% of reinf. required	ρ_t	=	0.076 %
Area of steel required for bending	$A_{st reqd}$	=	261 mm ²

For Tension

Maximum axial Tensile force	P_{xx}	=	2 kN
Area of tension steel required	$A_{st-T reqd}$	=	$(P/2)/0.87f_y$ 2 mm ²
Total area of steel required		=	$A_{st-B} + A_{st-T}$ 262 mm ²

Provide	=	16 mm	@ 150
&	=	0 mm	@ 200 alternately

% of tension reinf. Provided	$\rho_{t, prov}$	=	0.392 %
Min. % of reinf	$\rho_{t, min}$	=	0.200 % (As per IS 456 Cl.No 32.5) both face
	$A_{st Provided}$	=	1340 mm ² safe

(c) VERTICAL Reinforcement - Max. Axial Tension Case

Corres. factored moment	Mu	=	10 kNm/m
Effective depth in X-dir	d	=	342 mm
	Mu/bd^2	=	0.088
% of reinf. required	ρ_t	=	0.020 %
Area of steel required for bending	$A_{st reqd}$	=	69 mm ²

For Tension

Maximum axial Tensile force	P_{xx}	=	104 kN
Area of tension steel required	$A_{st-T reqd}$	=	$(P/2)/0.87f_y$ 120 mm ²
Total area of steel required		=	$A_{st-B} + A_{st-T}$ 189 mm ²

Provide	=	16 mm	@ 150
&	=	0 mm	@ 200 alternately

% of tension reinf. Provided	$\rho_{t, prov}$	=	0.392 %
Min. % of reinf	$\rho_{t, min}$	=	0.200 % (As per IS 456 Cl.No 32.5) both face
	$A_{st Provided}$	=	1340 mm ² safe

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SUMMARY OF FORCES FROM STAAD : STAAD GROUP NAME: LONGWALL1

	Plate	L/C	Shear	Membrane			Bending Moment			
			SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Mx kNm/m	My kNm/m	Mxy kNm/m
Max Qx	1695	205 1.5DL+1	0.41	0.018	-0.456	-0.208	-0.013	-79.592	-11.054	0.851
Min Qx	1707	205 1.5DL+1	-0.41	0.014	-0.455	-0.318	-0.012	-79.743	-10.946	-0.479
Max Qy	1350	205 1.5DL+1	0.004	0.311	-0.103	-0.475	-0.016	-0.882	33.114	0.303
Min Qy	1324	205 1.5DL+1	-0.001	-0.315	-0.109	-0.519	-0.003	0.731	-34.664	-0.115
Max Sx	1408	221 1.5DL+1	-0.149	0.047	0.191	0.048	0.108	-20.298	1.914	-1.15
Min Sx	1695	205 1.5DL+1	0.41	0.018	-0.456	-0.208	-0.013	-79.592	-11.054	0.851
Max Sy	1331	218 1.5DL+1	-0.133	-0.098	0.154	0.245	0.016	12.396	-5.928	-4.328
Min Sy	1324	219 1.5DL+1	-0.001	-0.044	0.041	-0.699	-0.003	-12.787	-33.258	-0.078
Max Sxy	1458	221 1.5DL+1	-0.083	0.036	0.185	-0.232	0.154	0.179	7.84	-2.112
Min Sxy	1502	219 1.5DL+1	0.079	0.026	0.173	-0.139	-0.161	-1.118	4.534	0.193
Max Mx	1772	205 1.5DL+1	0.407	0.005	-0.453	-0.333	0.011	81.545	11.418	-0.594
Min Mx	1759	205 1.5DL+1	-0.409	-0.004	-0.454	-0.309	-0.013	-81.27	-11.513	0.458
Max My	1350	206 1.5DL+1	0.004	0.099	0.049	-0.537	-0.017	12.064	37.118	0.216
Min My	1324	206 1.5DL+1	-0.001	-0.101	0.043	-0.578	-0.004	-12.232	-38.244	-0.085
Max Mxy	1424	205 1.5DL+1	0.122	-0.033	-0.237	-0.28	-0.122	-2.149	2.708	16.912
Min Mxy	1432	205 1.5DL+1	-0.121	-0.035	-0.234	-0.307	0.102	-2.209	2.586	-17.049

DESIGN FOR BENDING

HORIZONTAL DIRECTION

(a) Maximum positive bending Moment in X direction

	Mx	=	82 kNm
	Mxy	=	-0.59 kNm
	Mxx	=	ABS(Mx)+ABS(Mxy)
	Mxx	=	82 kNm
Corresponding Axial stress in X dir	Sx	=	0.000 N/mm ²
	Sxy	=	0.0110 N/mm ²
	Sxx	=	Sx+Abs(Sxy)
	Sxx	=	0.01 N/mm²
Axial Force in X direction	P	=	Sxx * b * D
	Pxx	=	4 kN

Plate No	Load case
1772	205 1.5DL+1.5E

(b) Maximum negative bending Moment in X direction

	Mx	=	-81 kNm
	Mxy	=	0.46 kNm
	Mxx	=	ABS(Mx)+ABS(Mxy)
	Mxx	=	82 kNm
Corresponding Axial stress in X dir	Sx	=	0.000 N/mm ²
	Sxy	=	-0.0130 N/mm ²
	Sxx	=	Sx+Abs(Sxy)
	Sxx	=	0.01 N/mm²
Axial Force in X direction	P	=	Sxx * b * D
	Pxx	=	5 kN

Plate No	Load case
1759	205 1.5DL+1.5E

(c) Maximum Axial stress in X direction

	Sx	=	0.191 N/mm ²
	Sxy	=	0.1080 N/mm ²
	Sxx	=	Sx+Abs(Sxy)
	Sxx	=	0.30 N/mm²
Axial Force in X direction	P	=	Sxx * b * D
	Pxx	=	120 kN

Plate No	Load case
1408	221 1.5DL+1.5E

Corresponding bending Moment in X direction	Mx	=	-20 kNm
	Mxy	=	-1.15 kNm
	Mxx	=	ABS(Mx)+ABS(Mxy)
	Mxx	=	21 kNm

Material:

Concrete grade 35 N/mm²

Steel grade 500 N/mm²

Cover:

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Clear cover 50 mm
Vert. bar dia. 16 mm

DESIGN FOR BENDING AND AXIAL TENSION

Depth required for bending

$$\begin{aligned} \text{Mu}/f_{ck}bd^2 &= 0.133 \\ \text{Maximum factored moment } \text{Mu} &= \text{Max of (Mxx)} \\ &= 82.1 \text{ kNm} \\ d \text{ reqd} &= \sqrt{\text{Mu}/(0.133 \cdot f_{ck} \cdot b)} \\ &= 132.8 \text{ mm} \\ D \text{ reqd} &= 207 \text{ mm} \\ D \text{ prov} &= 400 \text{ mm} \end{aligned}$$

(a) HORIZONTAL Reinforcement in inner face of wall (X-Dirn-Positive Reinf) - Max. Mx case

For Bending

$$\begin{aligned} \text{Max. factored moment } \text{Mu} &= 82 \text{ kNm/m} \\ \text{Effective depth in X-dir } d &= 392 \text{ mm} \\ \text{Mu}/bd^2 &= 0.535 \\ \% \text{ of reinf. required } \rho_t &= 0.125 \% \\ \text{Area of steel required for bending } \text{Ast-B reqd} &= 491 \text{ mm}^2 \end{aligned}$$

For Tension

$$\begin{aligned} \text{Maximum axial Tensile force } \text{Pxx} &= 4 \text{ kN} \\ \text{Area of tension steel required } \text{Ast-T reqd} &= (P/2)/0.87f_y \\ &= 5 \text{ mm}^2 \\ \text{Total area of steel required} &= \text{Ast-B} + \text{Ast-T} \\ &= 496 \text{ mm}^2 \end{aligned}$$

Provide	=	16 mm	@ 150
&	=	0 mm	@ 400 alternately

$$\begin{aligned} \% \text{ of tension reinf. Provided } \rho_{t, \text{prov}} &= 0.342 \% \\ \text{Min. \% of reinf } \rho_{t, \text{min}} &= 0.200 \% \quad (\text{As per IS 456 Cl.No 32.5) both face} \\ \text{Ast Provided} &= 1340 \text{ mm}^2 \quad \text{safe} \end{aligned}$$

(b) HORIZONTAL Reinforcement in outer face of wall (X dirn -Negative reinf)- Max. Mx case

$$\begin{aligned} \text{Max. factored moment } \text{Mu} &= 82 \text{ kNm/m} \\ \text{Effective depth in X-dir } d &= 326 \text{ mm} \\ \text{Mu}/bd^2 &= 0.769 \\ \% \text{ of reinf. required } \rho_t &= 0.182 \% \\ \text{Area of steel required for bending } \text{Ast reqd} &= 592 \text{ mm}^2 \end{aligned}$$

For Tension

$$\begin{aligned} \text{Maximum axial Tensile force } \text{Pxx} &= 5 \text{ kN} \\ \text{Area of tension steel required } \text{Ast-T reqd} &= (P/2)/0.87f_y \\ &= 6 \text{ mm}^2 \\ \text{Total area of steel required} &= \text{Ast-B} + \text{Ast-T} \\ &= 598 \text{ mm}^2 \end{aligned}$$

Provide	=	16 mm	@ 150
&	=	0 mm	@ 200 alternately

$$\begin{aligned} \% \text{ of tension reinf. Provided } \rho_{t, \text{prov}} &= 0.411 \% \\ \text{Min. \% of reinf } \rho_{t, \text{min}} &= 0.200 \% \quad (\text{As per IS 456 Cl.No 32.5) both face} \\ \text{Ast Provided} &= 1340 \text{ mm}^2 \quad \text{safe} \end{aligned}$$

(c) HORIZONTAL Reinforcement - Max. Axial Tension Case

$$\begin{aligned} \text{Corres. factored moment } \text{Mu} &= 21 \text{ kNm/m} \\ \text{Effective depth in X-dir } d &= 326 \text{ mm} \\ \text{Mu}/bd^2 &= 0.202 \\ \% \text{ of reinf. required } \rho_t &= 0.047 \% \\ \text{Area of steel required for bending } \text{Ast reqd} &= 152 \text{ mm}^2 \end{aligned}$$

For Tension

$$\begin{aligned} \text{Maximum axial Tensile force } \text{Pxx} &= 120 \text{ kN} \\ \text{Area of tension steel required } \text{Ast-T reqd} &= (P/2)/0.87f_y \\ &= 137 \text{ mm}^2 \\ \text{Total area of steel required} &= \text{Ast-B} + \text{Ast-T} \\ &= 290 \text{ mm}^2 \end{aligned}$$

Provide	=	16 mm	@ 150
&	=	0 mm	@ 400 alternately

$$\begin{aligned} \% \text{ of tension reinf. Provided } \rho_{t, \text{prov}} &= 0.411 \% \\ \text{Min. \% of reinf } \rho_{t, \text{min}} &= 0.200 \% \quad (\text{As per IS 456 Cl.No 32.5) both face} \\ \text{Ast Provided} &= 1340 \text{ mm}^2 \quad \text{safe} \end{aligned}$$

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$$\begin{aligned}\text{Elastic strain at surface } e_1 &= \frac{f_s \cdot x (h - x)}{E_s \cdot x (d - x)} \\ &= \frac{42.24 \cdot x (500 - 131.88)}{200000 \cdot x (437.5 - 131.88)} \\ &= 0.000254 \\ \text{Stiffening effect of concrete } e_2 &= \frac{b \cdot (h - x)^2}{600000 \cdot A_s \cdot (d - x)} \\ &= \frac{1000 \cdot x (500 - 131.88)}{600000 \cdot x 3506 \cdot (438 - 131.88)} \\ &= 0.0002108 \\ e_m &= e_1 - e_2 \\ &= 0.000254 - 0.0002108 \\ &= 0.000044 > 0\end{aligned}$$

Check the crack width

$$\begin{aligned}\text{Crack width 'W'} &= \frac{3 \cdot e_m \cdot a_{cr}}{1 + 2 \cdot x (a_{cr} - C_{min}) / (h - x)} \\ a_{cr} &= \sqrt{s/2^2 + dc^2 - db/2} \\ &= \sqrt{70^2 + 62.5 \cdot -25 / 2} \\ &= 81.34 \text{ mm} \\ \text{Hence 'W'} &= \frac{3 \cdot 0.000044 \cdot 81.34}{1 + 2 \cdot x (81.34 - 50) / (500 - 131.88)} \\ &= 0.01 < 0.10 \\ &\text{Hence the reinforcement is ok}\end{aligned}$$

Annexure E

Design of Tank Top Slab

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Engineering Concepts

SUMMARY OF FORCES FROM STAAD : STAAD GROUP NAME: SLAB

	Plate	L/C	Shear	Membrane			Bending Moment			
			SQX (local) N/mm ²	SQY (local) N/mm ²	SX (local) N/mm ²	SY (local) N/mm ²	SXY (local) N/mm ²	Mx kNm/m	My kNm/m	Mxy kNm/m
Max Qx	2353	212 1.5	0.143	-0.046	-0.093	-0.04	0.037	5.849	7.202	-6.417
Min Qx	2316	205 1.5	-0.208	-0.057	-0.253	0	-0.054	11.707	0.729	-0.558
Max Qy	2315	205 1.5	-0.1	0.14	-0.275	-0.055	-0.025	6.257	1.344	-3.072
Min Qy	2342	206 1.5	-0.048	-0.229	-0.024	-0.008	-0.01	3.687	-0.112	8.999
Max Sx	2353	218 1.5	0.105	-0.035	0.088	0.044	-0.036	4.469	5.803	-5.075
Min Sx	2342	205 1.5	-0.078	-0.152	-0.38	-0.84	-0.294	-2.988	-17.477	-3.253
Max Sy	2342	219 1.5	-0.038	-0.172	0.017	0.08	0.021	2.799	1.654	6.901
Min Sy	2342	205 1.5	-0.078	-0.152	-0.38	-0.84	-0.294	-2.988	-17.477	-3.253
Max Sxy	2333	205 1.5	0.007	0.023	-0.151	-0.281	0.145	-3.155	-11.496	1.981
Min Sxy	2342	205 1.5	-0.078	-0.152	-0.38	-0.84	-0.294	-2.988	-17.477	-3.253
Max Mx	2392	212 1.5	0.016	-0.01	-0.047	-0.001	0	19.051	0.847	-1.12
Min Mx	2311	205 1.5	0.068	-0.003	-0.215	-0.124	0.011	-18.739	-4.974	-1.231
Max My	2340	212 1.5	0.037	-0.046	-0.069	-0.043	0.034	-0.587	13.217	1.655
Min My	2371	205 1.5	-0.002	0.061	-0.122	-0.234	0.034	-4.459	-17.628	-0.549
Max Mxy	2316	212 1.5	-0.169	-0.077	-0.174	-0.024	-0.06	15.928	7.721	11.829
Min Mxy	2353	212 1.5	0.143	-0.046	-0.093	-0.04	0.037	5.849	7.202	-6.417

DESIGN FOR BENDING

VERTICAL DIRECTION

(a) Maximum positive bending Moment in Y direction

	My	=	13.22 kNm
	Mxy	=	1.66 kNm
	Myy	=	ABS(My)+ABS(Mxy)
	Myy	=	15 kNm
Corresponding Axial stress in Y directio	Sy	=	0.000 N/mm ²
	Sxy	=	0.0340 N/mm ²
	Syy	=	Sy+Abs(Sxy)
	Syy	=	0.03 N/mm²
Axial Force in Y direction	P	=	Syy * b * D
	Pyy	=	7 kN

Plate No	Load case
2340	212 1.5DL+1.5E

(b) Maximum negative bending Moment in Y direction

	My	=	-17.63 kNm
	Mxy	=	-0.55 kNm
	Myy	=	ABS(My)+ABS(Mxy)
	Myy	=	18 kNm
Corresponding Axial stress in Y directio	Sy	=	0.000 N/mm ²
	Sxy	=	0.0340 N/mm ²
	Syy	=	Sy+Abs(Sxy)
	Syy	=	0.03 N/mm²
Axial Force in Y direction	P	=	Syy * b * D
	Pyy	=	7 kN

Plate No	Load case
2371	205 1.5DL+1.5E

(c) Maximum Axial stress in Y direction

	Sy	=	0.080 N/mm ²
	Sxy	=	0.0210 N/mm ²
	Syy	=	Sy+Abs(Sxy)
	Syy	=	0.10 N/mm²
Axial Force in Y direction	P	=	Syy * b * D
	Pyy	=	20 kN

Plate No	Load case
2342	219 1.5DL+1.5E

Corresponding bending Moment in Y direction	My	=	2 kNm
	Mxy	=	6.90 kNm
	Myy	=	ABS(My)+ABS(Mxy)
	Myy	=	9 kNm

Material:

Concrete grade 35 N/mm²

Steel grade 500 N/mm²

Cover:

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Clear cover 25 mm

DESIGN FOR BENDING AND AXIAL TENSION

Depth required for bending

	$M_u/fckbd^2$	=	0.133
Maximum factored moment	M_u	=	Max of (M_{yy}) 18.2 kNm
	d_{reqd}	=	$\sqrt{M_u/(0.133 \cdot f_{ck} \cdot b)}$ 62.5 mm
	D_{reqd}	=	93 mm
	D_{prov}	=	200 mm

(a) Reinforcement Inner face of slab (Y-Dirn-Positive Reinf) - Max. M_{yy} case

For Bending

Max. factored moment	M_u	=	15 kNm/m
Effective depth in X-dir	d	=	169 mm
	M_u/bd^2	=	0.521
% of reinf. required	ρ_t	=	0.122 %
Area of steel required for bending	$A_{st-B reqd}$	=	206 mm ²

For Tension

Maximum axial Tensile force	P_{xx}	=	7 kN
Area of tension steel required	$A_{st-T reqd}$	=	$(P/2)/0.87f_y$ 8 mm ²
Total area of steel required		=	$A_{st-B} + A_{st-T}$ 214 mm²

Provide	=	12 mm	@ 150
&	=	0 mm	@ 150 alternately

% of tension reinf. Provided	$\rho_{t, prov}$	=	0.446 %
Min. % of reinf	$\rho_{t, min}$	=	0.200 % (As per IS 456 Cl.No 32.5) both face
Ast Provided		=	754 mm² safe

(b) Reinforcement in Outer face of slab (Y dirn -Negative reinf)- Max. M_{yy} case

Max. factored moment	M_u	=	18 kNm/m
Effective depth in X-dir	d	=	169 mm
	M_u/bd^2	=	0.636
% of reinf. required	ρ_t	=	0.150 %
Area of steel required for bending	$A_{st reqd}$	=	253 mm ²

For Tension

Maximum axial Tensile force	P_{xx}	=	7 kN
Area of tension steel required	$A_{st-T reqd}$	=	$(P/2)/0.87f_y$ 8 mm ²
Total area of steel required		=	$A_{st-B} + A_{st-T}$ 261 mm²

Provide	=	12 mm	@ 150
&	=	0 mm	@ 200 alternately

% of tension reinf. Provided	$\rho_{t, prov}$	=	0.446 %
Min. % of reinf	$\rho_{t, min}$	=	0.200 % (As per IS 456 Cl.No 32.5) both face
Ast Provided		=	754 mm² safe

(c) VERTICAL Reinforcement - Max. Axial Tension Case

Corres. factored moment	M_u	=	9 kNm/m
Effective depth in X-dir	d	=	169 mm
	M_u/bd^2	=	0.300
% of reinf. required	ρ_t	=	0.070 %
Area of steel required for bending	$A_{st reqd}$	=	118 mm ²

For Tension

Maximum axial Tensile force	P_{xx}	=	20 kN
Area of tension steel required	$A_{st-T reqd}$	=	$(P/2)/0.87f_y$ 23 mm ²
Total area of steel required		=	$A_{st-B} + A_{st-T}$ 141 mm²

Provide	=	12 mm	@ 150
&	=	0 mm	@ 200 alternately

% of tension reinf. Provided	$\rho_{t, prov}$	=	0.446 %
Min. % of reinf	$\rho_{t, min}$	=	0.200 % (As per IS 456 Cl.No 32.5) both face
Ast Provided		=	754 mm² safe

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SUMMARY OF FORCES FROM STAAD : STAAD GROUP NAME: SLAB

	Plate	L/C	Shear	Membrane			Bending Moment			My kNm/m	Mxy kNm/m
			SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Mx kNm/m			
Max Qx	2353	212 1.5DL+1	0.143	-0.046	-0.093	-0.04	0.037	5.849	7.202	-6.417	
Min Qx	2316	205 1.5DL+1	-0.208	-0.057	-0.253	0	-0.054	11.707	0.729	-0.558	
Max Qy	2315	205 1.5DL+1	-0.1	0.14	-0.275	-0.055	-0.025	6.257	1.344	-3.072	
Min Qy	2342	206 1.5DL+1	-0.048	-0.229	-0.024	-0.008	-0.01	3.687	-0.112	8.999	
Max Sx	2353	218 1.5DL+1	0.105	-0.035	0.088	0.044	-0.036	4.469	5.803	-5.075	
Min Sx	2342	205 1.5DL+1	-0.078	-0.152	-0.38	-0.84	-0.294	-2.988	-17.477	-3.253	
Max Sy	2342	219 1.5DL+1	-0.038	-0.172	0.017	0.08	0.021	2.799	1.654	6.901	
Min Sy	2342	205 1.5DL+1	-0.078	-0.152	-0.38	-0.84	-0.294	-2.988	-17.477	-3.253	
Max Sxy	2333	205 1.5DL+1	0.007	0.023	-0.151	-0.281	0.145	-3.155	-11.496	1.981	
Min Sxy	2342	205 1.5DL+1	-0.078	-0.152	-0.38	-0.84	-0.294	-2.988	-17.477	-3.253	
Max Mx	2392	212 1.5DL+1	0.016	-0.01	-0.047	-0.001	0	19.051	0.847	-1.12	
Min Mx	2311	205 1.5DL+1	0.068	-0.003	-0.215	-0.124	0.011	-18.739	-4.974	-1.231	
Max My	2340	212 1.5DL+1	0.037	-0.046	-0.069	-0.043	0.034	-0.587	13.217	1.655	
Min My	2371	205 1.5DL+1	-0.002	0.061	-0.122	-0.234	0.034	-4.459	-17.628	-0.549	
Max Mxy	2316	212 1.5DL+1	-0.169	-0.077	-0.174	-0.024	-0.06	15.928	7.721	11.829	
Min Mxy	2353	212 1.5DL+1	0.143	-0.046	-0.093	-0.04	0.037	5.849	7.202	-6.417	

DESIGN FOR BENDING

HORIZONTAL DIRECTION

(a) Maximum positive bending Moment in X direction

$$\begin{aligned}
 M_x &= 19 \text{ kNm} \\
 M_{xy} &= -1.12 \text{ kNm} \\
 M_{xx} &= \text{ABS}(M_x) + \text{ABS}(M_{xy}) \\
 \mathbf{M_{xx}} &= \mathbf{20 \text{ kNm}} \\
 \text{Corresponding Axial stress in X dir} \quad S_x &= 0.000 \text{ N/mm}^2 \\
 S_{xy} &= 0.0000 \text{ N/mm}^2 \\
 S_{xx} &= S_x + \text{Abs}(S_{xy}) \\
 \mathbf{S_{xx}} &= \mathbf{0.00 \text{ N/mm}^2} \\
 \text{Axial Force in X direction} \quad P &= S_{xx} * b * D \\
 P_{xx} &= \mathbf{0 \text{ kN}}
 \end{aligned}$$

Plate No	Load case
2392	212 1.5DL+1.5T

(b) Maximum negative bending Moment in X direction

$$\begin{aligned}
 M_x &= -19 \text{ kNm} \\
 M_{xy} &= -1.23 \text{ kNm} \\
 M_{xx} &= \text{ABS}(M_x) + \text{ABS}(M_{xy}) \\
 \mathbf{M_{xx}} &= \mathbf{20 \text{ kNm}} \\
 \text{Corresponding Axial stress in X dir} \quad S_x &= 0.000 \text{ N/mm}^2 \\
 S_{xy} &= 0.0110 \text{ N/mm}^2 \\
 S_{xx} &= S_x + \text{Abs}(S_{xy}) \\
 \mathbf{S_{xx}} &= \mathbf{0.01 \text{ N/mm}^2} \\
 \text{Axial Force in X direction} \quad P &= S_{xx} * b * D \\
 P_{xx} &= \mathbf{2 \text{ kN}}
 \end{aligned}$$

Plate No	Load case
2311	205 1.5DL+1.5T

(c) Maximum Axial stress in X direction

$$\begin{aligned}
 S_x &= 0.088 \text{ N/mm}^2 \\
 S_{xy} &= -0.0360 \text{ N/mm}^2 \\
 S_{xx} &= S_x + \text{Abs}(S_{xy}) \\
 \mathbf{S_{xx}} &= \mathbf{0.12 \text{ N/mm}^2} \\
 \text{Axial Force in X direction} \quad P &= S_{xx} * b * D \\
 P_{xx} &= \mathbf{25 \text{ kN}} \\
 \text{Corresponding bending Moment in X direction} \\
 M_x &= 4 \text{ kNm} \\
 M_{xy} &= -5.08 \text{ kNm} \\
 M_{xx} &= \text{ABS}(M_x) + \text{ABS}(M_{xy}) \\
 \mathbf{M_{xx}} &= \mathbf{10 \text{ kNm}}
 \end{aligned}$$

Plate No	Load case
2353	218 1.5DL+1.5T

Material:

Concrete grade **35** N/mm²

Steel grade **500** N/mm²

Cover:

Analysis and Design of Sump Pit

www.rcengstudios.com

Engineering Concepts

Clear cover 25 mm
Vert. bar dia. 12 mm

DESIGN FOR BENDING AND AXIAL TENSION

Depth required for bending

$$\begin{aligned} \mu/fckbd^2 &= 0.133 \\ \text{Maximum factored moment } \mu &= \text{Max of } (M_{xx}) \\ &= 20.2 \text{ kNm} \\ d \text{ reqd} &= \sqrt{\mu/(0.133*fck*b)} \\ &= 65.8 \text{ mm} \\ D \text{ reqd} &= 109 \text{ mm} \\ D \text{ prov} &= 200 \text{ mm} \end{aligned}$$

(a) Reinforcement in inner face of slab (X-Dirn-Positive Reinf) - Max. Mx case

For Bending

$$\begin{aligned} \text{Max. factored moment } \mu &= 20 \text{ kNm/m} \\ \text{Effective depth in X-dir } d &= 194 \text{ mm} \\ \mu/bd^2 &= 0.536 \\ \% \text{ of reinf. required } \rho_t &= 0.126 \% \\ \text{Area of steel required for bending } A_{st-B} \text{ reqd} &= 244 \text{ mm}^2 \end{aligned}$$

For Tension

$$\begin{aligned} \text{Maximum axial Tensile force } P_{xx} &= 0 \text{ kN} \\ \text{Area of tension steel required } A_{st-T} \text{ reqd} &= (P/2)/0.87f_y \\ &= 0 \text{ mm}^2 \\ \text{Total area of steel required} &= A_{st-B} + A_{st-T} \\ &= 244 \text{ mm}^2 \end{aligned}$$

Provide	=	12 mm	@ 150
&	=	0 mm	@ 400 alternately

$$\begin{aligned} \% \text{ of tension reinf. Provided } \rho_{t, \text{prov}} &= 0.389 \% \\ \text{Min. \% of reinf } \rho_{t, \text{min}} &= 0.200 \% \quad (\text{As per IS 456 Cl.No 32.5}) \text{ both face} \\ \text{Ast Provided} &= 754 \text{ mm}^2 \quad \text{safe} \end{aligned}$$

(b) Reinforcement in outer face of slab (X dirn -Negative reinf)- Max. Mx case

$$\begin{aligned} \text{Max. factored moment } \mu &= 20 \text{ kNm/m} \\ \text{Effective depth in X-dir } d &= 157 \text{ mm} \\ \mu/bd^2 &= 0.810 \\ \% \text{ of reinf. required } \rho_t &= 0.192 \% \\ \text{Area of steel required for bending } A_{st} \text{ reqd} &= 301 \text{ mm}^2 \end{aligned}$$

For Tension

$$\begin{aligned} \text{Maximum axial Tensile force } P_{xx} &= 2 \text{ kN} \\ \text{Area of tension steel required } A_{st-T} \text{ reqd} &= (P/2)/0.87f_y \\ &= 3 \text{ mm}^2 \\ \text{Total area of steel required} &= A_{st-B} + A_{st-T} \\ &= 303 \text{ mm}^2 \end{aligned}$$

Provide	=	12 mm	@ 150
&	=	0 mm	@ 200 alternately

$$\begin{aligned} \% \text{ of tension reinf. Provided } \rho_{t, \text{prov}} &= 0.480 \% \\ \text{Min. \% of reinf } \rho_{t, \text{min}} &= 0.200 \% \quad (\text{As per IS 456 Cl.No 32.5}) \text{ both face} \\ \text{Ast Provided} &= 754 \text{ mm}^2 \quad \text{safe} \end{aligned}$$

(c) HORIZONTAL Reinforcement - Max. Axial Tension Case

$$\begin{aligned} \text{Corres. factored moment } \mu &= 10 \text{ kNm/m} \\ \text{Effective depth in X-dir } d &= 157 \text{ mm} \\ \mu/bd^2 &= 0.387 \\ \% \text{ of reinf. required } \rho_t &= 0.090 \% \\ \text{Area of steel required for bending } A_{st} \text{ reqd} &= 142 \text{ mm}^2 \end{aligned}$$

For Tension

$$\begin{aligned} \text{Maximum axial Tensile force } P_{xx} &= 25 \text{ kN} \\ \text{Area of tension steel required } A_{st-T} \text{ reqd} &= (P/2)/0.87f_y \\ &= 29 \text{ mm}^2 \\ \text{Total area of steel required} &= A_{st-B} + A_{st-T} \\ &= 170 \text{ mm}^2 \end{aligned}$$

Provide	=	12 mm	@ 150
&	=	0 mm	@ 400 alternately

$$\begin{aligned} \% \text{ of tension reinf. Provided } \rho_{t, \text{prov}} &= 0.480 \% \\ \text{Min. \% of reinf } \rho_{t, \text{min}} &= 0.200 \% \quad (\text{As per IS 456 Cl.No 32.5}) \text{ both face} \\ \text{Ast Provided} &= 754 \text{ mm}^2 \quad \text{safe} \end{aligned}$$

Annexure F Soil Report
