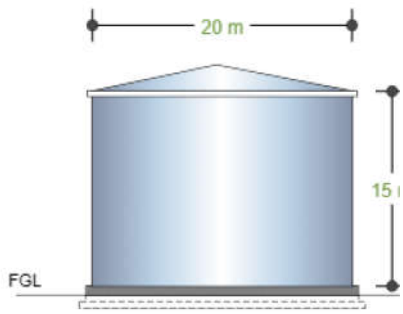
1.0 INPUT

1.1 Design Options

API 650: Enter Tank No



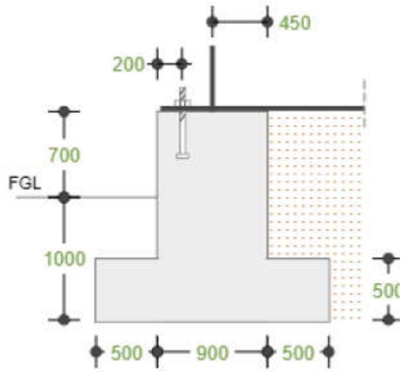
ELEVATION

Tank No	**Enter Tank No**
Foundation Type	**Soil Supported**
Tank Type	**API 650**
Design Standard	**British Standard**
Unit	**SI Unit**

1.2 Tank Data

Roof Type			**Floating Roof(External)**
Tank Inner Diameter	D_i	=	**20000** mm
Shell Height	H_t	=	**15000** mm
Roof Height	H_r	=	**2000** mm
Bolt Center Diameter	D_{bcd}	=	**20500** mm
Corrosion Allowance	C_{af}	=	**0** %

1.3 Foundation Data



RING BEAM FOUNDATION

Depth of Foundation	D_f	=	**1000** mm
Height of Ring Beam Above Ground	H_{ag}	=	**700** mm
Width of Ring Beam	W_w	=	**900** mm
Width in Contact with Fluid	W_{wf}	=	**450** mm
Thickness of Footing	T_f	=	**500** mm
Width of Footing Inside Ring Beam	W_{fi}	=	**500** mm
Width of Footing Outside Ring Beam	W_{fo}	=	**500** mm

1.4 Grade Slab

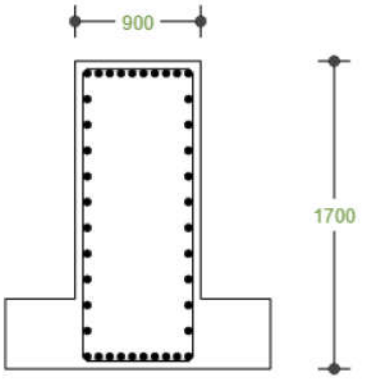
Grade Slab	**None**

1.5 Rebars and Anchor Bolt

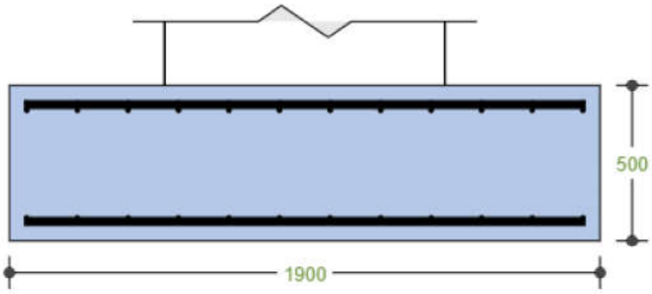
1.5.1 Reinforcement

Clear Cover for Ring Beam	C_{rb}	=	**50** mm
Clear Cover for Footing	C_{foot}	=	**50** mm

<u>Ring Beam and Footing Reinforcement</u>



Top and Bottom Layers (1): 10 - 25φ each.
Intermediate Layers (2): 10 - 25φ each. Total:19635 mm² (1.28%)
Vertical: 12φ - 120mm c/c (1885 mm²/m - 0.21%)



Bottom Main: 25φ - 100 mm c/c (4909 mm² - 0.98 %)
Bottom Secondary: 12φ - 150 mm c/c (754 mm² - 0.15 %)
Top Main: 25φ - 120 mm c/c (4091 mm² - 0.82 %)
Top Secondary: 12φ - 150 mm c/c (754 mm² - 0.15 %)

1.5.2 Anchor Bolts

Bolt Grade	f_b	=	**4.6**
Bolt Yield Strength	Y_b	=	**240** N/mm²
Bolt Ultimate Strength	U_b	=	**400** N/mm²
Bolt Size	d	=	**M20**
No. of Anchor Bolts	N_{ab}	=	**30**

1.5.3 Bolt Anchorage

Anchorage Tension Capacity	C_t	=	**50** kN
Anchorage Shear Capacity	C_s	=	**50** kN

1.6 Soil

Allowable Increase of SBC for Test	SBC_t	=	**20** %
Allowable Increase of SBC for Wind	SBC_w	=	**33** %
Allowable Increase of SBC for Seismic	SBC_s	=	**33** %
Allowable Safe Bearing Pressure	SBC	=	**200** kN/m²
Unit Weight of Soil	γ_{soil}	=	**18.5** kN/m³
Angle of Internal Friction	Φ	=	**30** deg
Pressure Coefficient Type	K	=	**Active (ka)**
Co-efficient of Friction	μ	=	**0.35**
Poisson's Ratio	v	=	**0.35**
Soil Elasticity Modulus	E_{so}	=	**36000** kN/m²
Hard Stratum Depth for Settlement	H_{sd}	=	**5000** mm
Allowable Differential Settlement	δ_{allow}	=	**12** mm
Ground Water Depth	H_{wt}	=	**460** mm
Density of Ground Water	γ_w	=	**9.81** kN/m³

1.7 Reinforced Concrete Properties

Density of Steel	γ_{steel}	=	**78.5** kN/m³
Density of Concrete	γ_{conc}	=	**24** kN/m³
Strength of Concrete	f_{cu}	=	**35** N/mm²
Strength of Reinforcement	f_y	=	**500** N/mm²
Strength of Links	f_{yv}	=	**500** N/mm²
Modulus of Elasticity of Steel	E_s	=	**200** kN/mm²

1.8 Material Partial Safety Factors

Concrete in Flexure/Compression	γ_{mc}	=	**1.5**
Concrete in Shear	γ_{mcs}	=	**1.25**

Reinforcement γ_{ms} = **1.15**

1.9 Stability Safety Factor

Factor of Safety against Sliding γ_{Slide} = **1.5**

Factor of Safety against Overturning γ_{Over} = **1.5**

Factor of Safety against Uplift γ_{Up} = **1.2**

1.10 Load Cases

Notation	Description
Ds	Dead Loads
De	Empty Weight
Do	Operating Weight
Dt	Test Weight
L	Live Load
S	Snow Load
W	Wind Load
Eo	Seismic Load

1.11 Loads Data

1.11.1 Tank Loads

Description	Axial Load (kN)	Shear at Tank Base (kN)	Moment at Tank Base (kN.m)
Empty Weight (De)	1500		
Tank Bottom Plate Weight (Dbp)	15		
Floating Roof Weight (Drs)	0		
Operating Weight (Do)	47500		
Test Weight (Dt)	49600		
Live Load (L)	150		
Snow Load (S)	200		
Wind Load (W)	100	250	2500
Seismic Load - Ring Beam Component (Vs, Mrw)		500	5000
Seismic Load - Slab Component (Ms)			5000

1.12 Load Combination

1.12.1 Serviceability Load Combinations

No	Combination
SLS1	Ds + Do
SLS2	Ds + Dt
SLS3	Ds + De + W
SLS4	Ds + Do + W
SLS5	Ds + Do + L
SLS6	Ds + Do + S
SLS7	Ds + De + 0.4L
SLS8	Ds + De + 0.4S
SLS9	Ds + Do + 0.4L
SLS10	Ds + Do + 0.4S
SLS11	Ds + Do + 0.1S + Eo

1.12.2 Ultimate Load Combinations

No	Combination
ULS1	1.4Ds + 1.4Do

1.12.2 Ultimate Load Combinations

No	Combination
ULS2	1.4Ds + 1.4Dt
ULS3	Ds + De + 1.4W
ULS4	1.4Ds + 1.4De + 1.4W
ULS5	Ds + Do + 1.4W
ULS6	1.4Ds + 1.4Do + 1.4W
ULS7	1.4Ds + 1.4Do + 1.6L
ULS8	1.4Ds + 1.4Do + 1.6S
ULS9	1.4Ds + 1.4De + 0.6L
ULS10	1.4Ds + 1.4De + 0.6S
ULS11	Ds + Do + 1.4Eo
ULS12	1.4Ds + 1.4Do + 0.2S + 1.4Eo

1.12.3 Additional Load Combinations

Change in Empty/Operating/Test Wt. **0** %

2.0 OUTPUT

2.1 Geometry of Tank Foundation

Inner Diameter of Ring Beam $D_{ir} = D_i - 2 * W_{wf}$ **19.1** m

Outer Diameter of Ring Beam $D_{or} = D_{ir} + 2 * W_w$ **20.9** m

Overall Depth of Ring Beam $H_{rb} = D_f + H_{ag}$ **1.7** m

Inner Diameter of Footing $D_{if} = D_{ir} - 2 * W_{fi}$ **18.1** m

Outer Diameter of Footing $D_{of} = D_{or} + 2 * W_{fo}$ **21.9** m

Width of Footing $W_f = W_{fi} + W_w + W_{fo}$ **1.9** m

2.2 Properties of Tank Foundation

Base Area of Ring Beam $A_r = \frac{\pi}{4} * (D_{or}^2 - D_{ir}^2)$ **56.5** m²

Area of Inner Footing Base $A_{if} = \frac{\pi * (D_{ir}^2 - D_{if}^2)}{4}$ **29.2** m²

Area of Footing Base $A_f = \frac{\pi * (D_{of}^2 - D_{if}^2)}{4}$ **119.4** m²

Surface Area of Soil Enclosed by Ring Beam $A_{sr} = \frac{\pi * D_{ir}^2}{4}$ **286.5** m²

Surface Area of Soil Enclosed by Footing Base $A_{sf} = \frac{\pi * D_{if}^2}{4}$ **257.3** m²

Section Modulus of Ring Foundation $S_r = \frac{\pi * (D_{of}^4 - D_{if}^4)}{32 * D_{of}}$ **550** m³

2.3 Load Calculation

[Tank Loads provided by the User / Vendor]

Cross Section Area of Tank $A_t = \frac{\pi * D_i^2}{4}$ **314.2** m²

Self-Weight of Ring Beam	$W_{rb} = A_r * (H_{rb} - T_f) * \gamma_{conc}$	**1628.6** kN
Self-Weight of Ring Footing	$W_{rf} = (A_f - A_r) * T_f * \gamma_{conc}$	**1432.6** kN
Weight of Soil on Footing Inside	$W_{sfi} = (A_{sr} - A_{sf}) * (H_{ag} + D_f - T_f) * \gamma_{soil}$	**648.6** kN
Weight of Soil on Footing Outside	$W_{sfo} = \frac{\pi}{4} * (D_{of}^2 - D_{or}^2) * (D_f - T_f) * \gamma_{soil}$	**310.9** kN
Weight of Soil Interior to Foundation	$W_{sf} = A_{sf} * H_{rb} * \gamma_{soil}$	**6729.2** kN
% of Tank Content Load to Ring Beam	$R_w = \frac{A_t - A_{sr}}{A_t} * 100$	**8.8** %
% of Tank Content Load to Footing Base	$R_g = \frac{A_t - A_{sf}}{A_t} * 100 - R_w$	**9.3** %
Tank Base Plate Load to Ring Beam	$W_{tr} = D_{bp} * R_w$	**1.3** kN
Tank Base Plate Load to Footing Base	$W_{tf} = D_{bp} * R_g$	**1.4** kN
Remaining Tank Base Plate Load	$D_{bpf} = D_{bp} - W_{tr} - W_{tf}$	**12.3** kN
Floating Roof Load to Ring Beam	$W_{rr} = D_{rs} * R_w$	**0** kN
Floating Roof Load to Footing Base	$W_{fr} = D_{rs} * R_g$	**0** kN
Design Floating Roof Load	$D_{fr} = W_{rr} + W_{fr}$	**0** kN
Remaining Floating Roof Load	$D_{rsf} = D_{rs} - D_{fr}$	**0** kN
Live Load to Ring Beam	$W_{lr} = L * R_w$	**13.2** kN
Live Load to Footing Base	$W_{lf} = L * R_g$	**14** kN
Design Live Load	$D_{Ll} = W_{lr} + W_{lf}$	**27.1** kN
Remaining Live Load	$D_{Llf} = L - D_{Ll}$	**0** kN
Snow Load to Ring Beam	$W_{sr} = S * R_w$	**17.6** kN
Snow Load to Footing Base	$W_{sf} = S * R_g$	**18.6** kN
Design Snow Load	$D_{sl} = W_{sr} + W_{sf}$	**36.2** kN
Remaining Snow Load	$D_{slf} = S - D_{sl}$	**163.8** kN
Shell Knife Edge Load	$W_{sk} = W_e - D_{bp} - W_{rp}$	**1485** kN
Empty Weight to Ring Beam	$E_w = W_{sk} + W_{tr}$	**1486.3** kN
Total Empty Weight	$W_{et} = E_{wv} + W_{tf}$	**1487.7** kN
Operating Content Load to Ring Beam	$O_{wr} = (D_o - D_e) * R_w$	**4046.8** kN
Operating Load to Footing Base	$O_{wf} = (D_o - D_e) * R_g$	**4278** kN
Total Operating Content Weight	$W_{ot} = O_{wrv} + O_{wf}$	**8324.8** kN
Remaining Operating Content Weight	$W_{otf} = D_o - D_e - W_{ot}$	**37675.2** kN
Testing Content Load to Ring Beam	$T_{wr} = (D_t - D_e) * R_w$	**4231.6** kN

Testing Content Load to Footing Base	$T_{wf} = (D_t - D_e) * R_g$	**4473.3** kN
Total Test Content Weight	$W_{tt} = T_{wrv} + T_{wf}$	**8704.9** kN
Remaining Test Content Weight	$W_{ttf} = D_t - D_e - W_{tt}$	**39395.1** kN

2.4 Buoyancy Load

Buoyancy Load	$B_L = A_f * (H_{wt} - D_f) * \gamma_w$	**-632.4** kN

2.5 Loads on Ring Foundation

Sl.No	Load Case	On Top of Ring Foundation			
		Axial (kN)		Shear (kN)	Moment (kN.m)
1	Dc - Dead (Self) Weight of Concrete = W_{rb} + W_{rf}	**3061.2**			
2	Ds - Dead (Self) Weight of Soil = W_{sfi} + W_{sfo}	**959.6**	**6729.2** *		
3	BL - Buoyancy Load = B_L	**-632.4**			
4	De - Dead (Empty / Self) Weight of Tank = W_{et}	**1487.7**	**12.3** *		
5	Drs - Floating Roof Weight	**0**	**0** *		
6	Do - Equipment Operating Content Weight = W_{ot}	**8324.8**	**37675.2** *		
7	Dt - Equipment Test Content Weight = W_{tt}	**8704.9**	**39395.1** *		
8	L - Live Load	**27.1**	**122.9** *		
9	S - Snow Load	**36.2**	**163.8** *		
10	WL - Wind Load			**250**	**2500**
11	Eo - Seismic Load Ring Beam Component			**500**	**5000**
12	Eo - Seismic Load Slab Component				**5000**

Note * : *The loads acting interior to the footing is considered only for Resisting Force Calculation in Sliding Check*

2.6 Stability Checks

2.6.1 Uplift Check

Sl.No	Downward Force (kN) Vertical Load	Upward Force (kN)	FOS	Status
SLS1	**13833.3**	**632.4**	**21.87**	**OK**
SLS2	**14213.3**	**632.4**	**22.47**	**OK**
SLS3	**5508.4**	**1120.2**	**4.92**	**OK**
SLS4	**13833.3**	**1120.2**	**12.35**	**OK**
SLS5	**13860.4**	**632.4**	**21.92**	**OK**
SLS6	**13869.5**	**632.4**	**21.93**	**OK**
SLS7	**5519.3**	**632.4**	**8.73**	**OK**
SLS8	**5522.9**	**632.4**	**8.73**	**OK**
SLS9	**13844.1**	**632.4**	**21.89**	**OK**
SLS10	**13847.8**	**632.4**	**21.9**	**OK**
SLS11	**13836.9**	**1608**	**8.6**	**OK**

2.6.2 Critical Combinations - Failure Case

No	Combination
CLC1	Ds + 0.9De + W
CLC2	Ds + De
CLC3	Ds + Do

2.6.3 Uplift Check - Critical Combination

Sl.No	Downward Force (kN) Vertical Load	Upward Force (kN)	FOS	Status
CLC1	**5359.7**	**1120.2**	**4.78**	**OK**
CLC2	**5508.4**	**632.4**	**8.71**	**OK**
CLC3	**13833.3**	**632.4**	**21.87**	**OK**

2.6.4 Check for Sliding

Sl.No	Resisting Force (kN) Vertical Load * µ	Sliding Force (kN) (Hor. Shear Force)	FOS	Status
SLS1	**20166.1**	**0**	**NA**	**OK**
SLS2	**20901.1**	**0**	**NA**	**OK**
SLS3	**4066.1**	**250**	**16.26**	**OK**
SLS4	**20166.1**	**250**	**80.66**	**OK**
SLS5	**20218.6**	**0**	**NA**	**OK**
SLS6	**20236.1**	**0**	**NA**	**OK**
SLS7	**4087.1**	**0**	**NA**	**OK**
SLS8	**4094.1**	**0**	**NA**	**OK**
SLS9	**20187.1**	**0**	**NA**	**OK**
SLS10	**20194.1**	**0**	**NA**	**OK**
SLS11	**20173.1**	**500**	**40.35**	**OK**

2.6.5 Check for Overturning

Distance from Center to Edge of Ring Footing B_r **10.95** m

Sl.No	Resisting Moment (kN.m) (Vertical Load * B_r)	Overturning Moment (kN.m) (Hor. Moments)	FOS	Status
SLS1	**144549.6**	**0**	**NA**	**OK**
SLS2	**148711.1**	**0**	**NA**	**OK**
SLS3	**53392.5**	**2925**	**18.25**	**OK**
SLS4	**144549.6**	**2925**	**49.42**	**OK**
SLS5	**144846.9**	**0**	**NA**	**OK**
SLS6	**144946**	**0**	**NA**	**OK**
SLS7	**53511.4**	**0**	**NA**	**OK**
SLS8	**53551**	**0**	**NA**	**OK**
SLS9	**144668.5**	**0**	**NA**	**OK**
SLS10	**144708.2**	**0**	**NA**	**OK**
SLS11	**144589.3**	**5850**	**24.72**	**OK**

2.6.6 Check for Bearing Pressure

Sl.No	Base Pressure Under Tank (kN/m^2)	Base Pressure Under Tank at Fdn Level (kN/m^2)	Max. Base Pressure Under Footing (kN/m^2)	Min. Base Pressure Under Footing (kN/m^2)	Contact %	Allowable Base Pressure (kN/m^2)	Status
SLS1	**146.47**	**177.92**	**110.58**	**NA**	**100**	**218.5**	**OK**
SLS2	**153.15**	**184.6**	**113.76**	**NA**	**100**	**258.5**	**OK**
SLS3	**0.05**	**31.5**	**46.16**	**35.53**	**100**	**284.5**	**OK**
SLS4	**146.47**	**177.92**	**115.9**	**105.26**	**100**	**284.5**	**OK**
SLS5	**146.95**	**178.4**	**110.81**	**NA**	**100**	**218.5**	**OK**
SLS6	**147.11**	**178.56**	**110.88**	**NA**	**100**	**218.5**	**OK**
SLS7	**0.24**	**31.69**	**40.94**	**NA**	**100**	**218.5**	**OK**

SLS8	**0.3**	**31.75**	**40.97**	**NA**	**100**	**218.5**	**OK**
SLS9	**146.66**	**178.11**	**110.67**	**NA**	**100**	**218.5**	**OK**
SLS10	**146.72**	**178.17**	**110.7**	**NA**	**100**	**218.5**	**OK**
SLS11	**152.9**	**184.35**	**121.24**	**99.97**	**100**	**284.5**	**OK**

Note 1 : *NA is displayed for Uniform Pressure distribution where Maximum and Minimum Bearing Pressure are same.*

2.7 Immediate Settlement Calculation

Ref: Foundation Analysis and Design - Bowles

Note : *Circular Foundation is converted into Equivalent Square Dimension*

Hard Stratum Depth $H = H_{sd}$ **5000** m

Foundation Depth $D = D_f$ **1000** m

2.7.1 At Tank Center

Foundation Breadth $B_c = \sqrt{\frac{\pi * D_i * D_i}{4}}$ **17.7** m

Foundation Length $L_c = \sqrt{\frac{\pi * D_i * D_i}{4}}$ **17.7** m

Length by Breadth Ratio $\frac{L_c}{B_c}$ **1**

Depth by Breadth Ratio $\frac{D}{B_c}$ **0.1**

Influence Factor I_{fc} **0.8**

$B' = \frac{B_c}{2}$ **8.9** m

$L' = \frac{L_c}{2}$ **8.9** m

Ratio 1 $M = \frac{L'}{B'}$ **1**

Ratio 2 $N = \frac{H}{B'}$ **0.6**

$$I_1 = \frac{1}{\pi} * \left(M * \left(ln \left(\frac{\left(1 + \sqrt{M^2 + 1}\right) * \sqrt{M^2 + N^2}}{M * \left(1 + \sqrt{M^2 + N^2 + 1}\right)} \right) \right) + ln \left(\frac{\left(M + \sqrt{M^2 + 1}\right) * \sqrt{1 + N^2}}{M + \left(\sqrt{M^2 + N^2 + 1}\right)} \right) \right)$$ **0.1**

$$I_2 = \frac{N}{2 * \pi} * tan^{-1} \left(\frac{M}{N * \sqrt{M^2 + N^2 + 1}} \right)$$ **0.1**

Influence Factor 2 $I_s = I_1 + \frac{1 - 2 * \mu}{1 - \mu} * I_2$ **0.1**

No of Corners at Center m **4**

Max. Bearing Pressure at Tank Center M_{bpc}

Settlement at Tank Center $\delta h_c = M_{bpc} * B' * \frac{1 - \mu^2}{E_{so}} * m * I_s * I_{fc}$

2.7.2 At Tank Edge

Foundation Breadth $B_e = \sqrt{\frac{\pi * D_{of} * D_{of}}{4}}$ **19.4** m

Foundation Length $L_e = \sqrt{\frac{\pi * D_{of} * D_{of}}{4}}$ **19.4** m

Length by Breadth Ratio	$\frac{L_e}{B_e}$	**1**
Depth by Breadth Ratio	$\frac{D}{B_e}$	**0.1**
Influence Factor	I_{fe}	**0.8**
	$B'' = B_e$	**19.4** m
	$L'' = L_e$	**19.4** m
Ratio 3	$M'' = \frac{L''}{B''}$	**1**
Ratio 4	$N'' = \frac{H}{B''}$	**0.3**

$$I_1'' = \frac{1}{\pi} * \left(M'' * \left(ln \left(\frac{\left(1 + \sqrt{M''^2 + 1}\right) * \sqrt{M''^2 + N''^2}}{M'' * \left(1 + \sqrt{M''^2 + N''^2 + 1}\right)} \right) \right) + ln \left(\frac{\left(M'' + \sqrt{M''^2 + 1}\right) * \sqrt{1 + N''^2}}{M'' + \left(\sqrt{M''^2 + N''^2 + 1}\right)} \right) \right)$$

0

$$I_2'' = \frac{N''}{2 * \pi} * tan - 1 \left(\frac{M''}{N'' * \sqrt{M''^2 + N''^2 + 1}} \right)$$ **0**

Influence Factor 3	$I_s'' = I_1'' + \left(\frac{1 - 2 * \mu}{1 - \mu} \right) * I_2''$	**0**
No of Corners at Edge	m''	**1**
Max Bearing Pressure under Foundation	M_{bpe}	
Settlement at Tank Edge	$\delta h_e = M_{bpe} * B'' * \frac{1 - \mu^2}{E_{so}} * m'' * I_s'' * I_{fe}$	
Differential Settlement	$\delta h = \delta h_c - \delta h_e$	

Sl No.	δh_c (mm)	δh_e (mm)	δh (mm)	δh_{allow} (mm)	Status
SLS1	9.6	1.2	8.4	12	Safe
SLS2	10.1	1.2	8.8	12	Safe
SLS3	0	0.5	0.5	12	Safe
SLS4	9.6	1.3	8.4	12	Safe
SLS5	9.6	1.2	8.4	12	Safe
SLS6	9.7	1.2	8.5	12	Safe
SLS7	0	0.4	0.4	12	Safe
SLS8	0	0.4	0.4	12	Safe
SLS9	9.6	1.2	8.4	12	Safe
SLS10	9.6	1.2	8.4	12	Safe
SLS11	10	1.3	8.7	12	Safe

2.8 Anchor Bolt Calculation

Ref: BS 5950-1 - 08

Effective Threaded area of Anchor	$A_{se} = \frac{\pi}{4} * \left(d - \frac{0.9743}{8} \right)^2$	**224.49** mm²	*ASME B1.1*

2.8.1 Steel Material Strength

Bolt Tension Strength	P_t	**240** N/mm²	*Table 34*
Tension Capacity of Bolts	$P_b = S_{ab} * A_{se}$		*cl 6.3.4.3*

Bolt Shear Strength	P_s	**160** N/mm²	*Table 30*
Shear Capacity of Bolts	$P_v = P_s * A_{se}$	**35.92** kN	*cl 6.3.2.1*
Anchorage Tension Capacity	$T_c = min(P_b, C_t)$		
Anchorage Shear Capacity	$S_c = min(P_v, C_s)$		
Anchorage Interaction	$I_{tsa} = \frac{T_{ab}}{T_c} + \frac{V_{ab}}{S_c}$		

Sl.No	Tension per Bolt (T_{ab}) (kN)	Allowable Yield Stress (S_{ab}) (N/mm²)	P_b (kN)	T_c (kN)	Shear per Bolt (V_{ab}) (kN)	S_c (kN)	I_{tsa}	Status
ULS1	**No Tension**	**100**	**22.4**	**22.4**	**0**	**35.9**	**0**	**Pass**
ULS2	**No Tension**	**133.33**	**29.9**	**29.9**	**0**	**35.9**	**0**	**Pass**
ULS3	**No Tension**	**192**	**43.1**	**43.1**	**11.7**	**35.9**	**0.325**	**Pass**
ULS4	**No Tension**	**192**	**43.1**	**43.1**	**11.7**	**35.9**	**0.325**	**Pass**
ULS5	**No Tension**	**133.33**	**29.9**	**29.9**	**11.7**	**35.9**	**0.325**	**Pass**
ULS6	**No Tension**	**133.33**	**29.9**	**29.9**	**11.7**	**35.9**	**0.325**	**Pass**
ULS7	**No Tension**	**100**	**22.4**	**22.4**	**0**	**35.9**	**0**	**Pass**
ULS8	**No Tension**	**100**	**22.4**	**22.4**	**0**	**35.9**	**0**	**Pass**
ULS9	**No Tension**	**100**	**22.4**	**22.4**	**0**	**35.9**	**0**	**Pass**
ULS10	**No Tension**	**100**	**22.4**	**22.4**	**0**	**35.9**	**0**	**Pass**
ULS11	**No Tension**	**192**	**43.1**	**43.1**	**23.3**	**35.9**	**0.65**	**Pass**
ULS12	**No Tension**	**192**	**43.1**	**43.1**	**23.3**	**35.9**	**0.65**	**Pass**

Note 1 : *Anchor bolt Capacity based on Ultimate Strength*

2.8.2 Anchor Bolt Check - Critical Combination

Sl.No	Tension per Bolt (T_{ab}) (kN)	Allowable Yield Stress (S_{ab}) (N/mm²)	P_b (kN)	T_c (kN)	Shear per Bolt (V_{ab}) (kN)	S_c (kN)	I_{tsa}	Status
CLC1	**No Tension**	**192**	**43.1**	**43.1**	**8.3**	**35.9**	**0**	**Pass**
CLC2	**No Tension**	**100**	**22.4**	**22.4**	**0**	**35.9**	**0**	**Pass**
CLC3	**No Tension**	**100**	**22.4**	**22.4**	**0**	**35.9**	**0.325**	**Pass**

Note : *Anchor bolt Capacity based on Ultimate Strength*

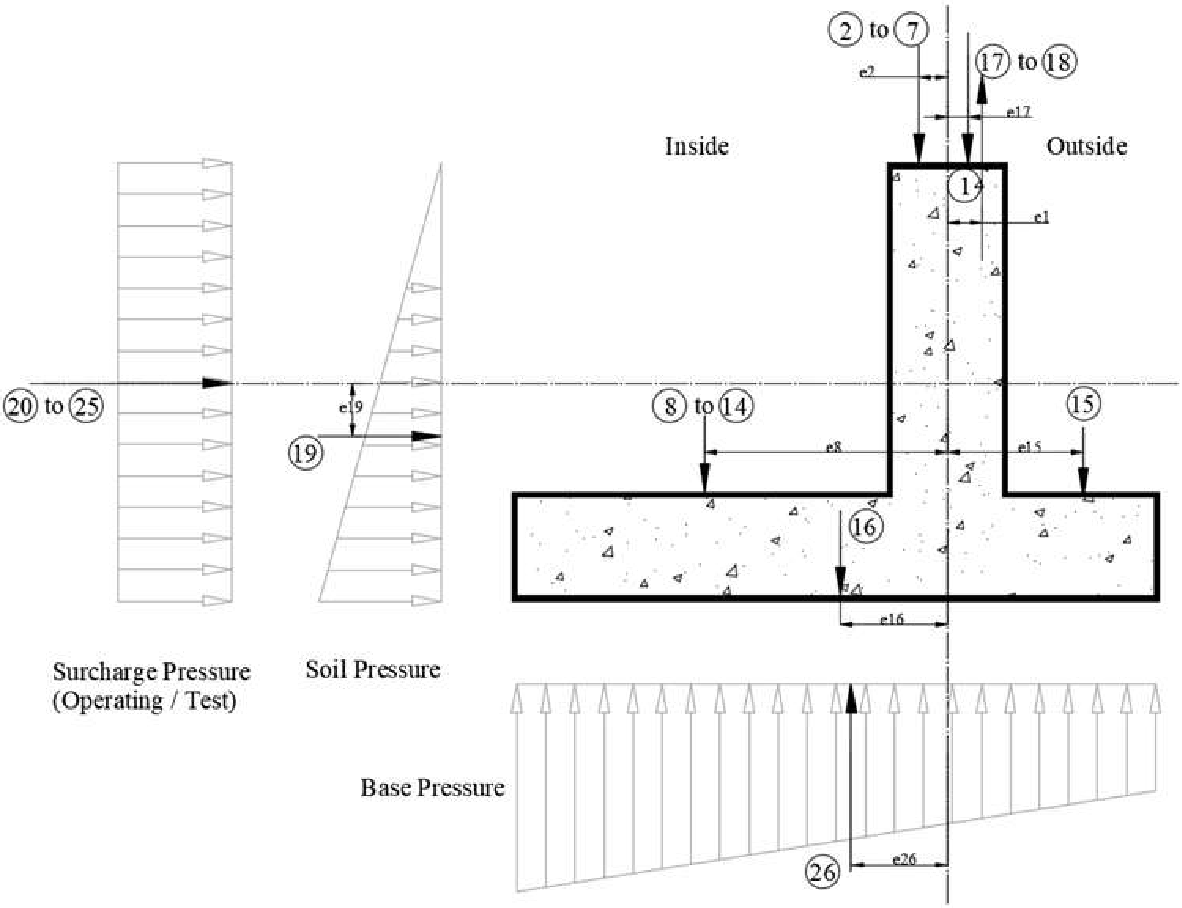
2.9 Ring Beam Design

2.9.1 Design of Circumferential Reinforcement for Ring Beam

Active Earth Pressure Coefficient	$k = \frac{1 - Sin(\Phi)}{1 + Sin(\Phi)}$	**0.3**
Radial Force due to Soil Pressure	$F_{soil} = 0.5 * k * \gamma_{soil} * H_{rb}^2$	**8.9** kN/m
Radial Force due to Operating Surcharge	$F_{oper} = k * \frac{D_o - D_e}{A_t} * H_{rb}$	**83** kN/m
Radial Force due to Test Surcharge	$F_{test} = k * \frac{D_t - D_e}{A_t} * H_{rb}$	**86.8** kN/m
Radial Force due to Base Plate	$F_{plate} = k * \frac{D_{bp} - W_{tr}}{A_{sr}} * H_{rb}$	**0** kN/m

Radial Force due to Floating Roof	$F_{roof} = k * \frac{D_{rs} - W_{fr}}{A_{sr}} * H_{rb}$	**0** kN/m
Radial Force due to Live Load	$F_{ll} = k * \frac{L - W_{lr}}{A_{sr}} * H_{rb}$	**0.3** kN/m
Radial Force due to Snow Load	$F_{sl} = k * \frac{S - W_{sr}}{A_{sr}} * H_{rb}$	**0.4** kN/m
Radial Force due to Sloshing Pressure	$F_{slosh} = k * \frac{M_s}{\frac{\pi}{32} * D_i^3} * H_{rb}$	**6.4** kN/m

2.9.2 Check for Torsion



Sl No.	Torsion Components	Vertical Forces (kN/m)	Horizontal Forces (kN/m)	Eccentricity (m)
1	Shell Edge Load	**23.6**		**0**
2	Live Load on Ring Beam	**0.2**		**0.2**
3	Snow Load on Ring Beam	**0.3**		**0.2**
4	Base Plate Load on Ring Beam	**0**		**0.2**
5	Floating Roof Weight on Ring Beam	**0**		**0.2**
6	Operating Liquid Load on Ring Beam	**65.9**		**0.2**
7	Test Liquid Load on Ring Beam	**68.9**		**0.2**
8	Live Load on Footing	**0.2**		**0.7**
9	Snow Load on Footing	**0.3**		**0.7**
10	Base Plate Load on Footing	**0**		**0.7**
11	Floating Roof Weight on Footing	**0**		**0.7**
12	Operating Liquid Load on Footing	**73.2**		**0.7**
13	Test Liquid Load on Footing	**76.6**		**0.7**
14	Soil Load on Inside Footing	**11.1**		**0.7**
15	Soil Load on Outside Footing	**4.6**		**-0.7**

16	Self-Weight of Foundation	**48.7**		**0**
17	Uplift Force - Wind Load	**-7.6**		**-0.2**
18	Uplift Force - Seismic Load	**-15.1**		**-0.2**
19	Force due to Soil Pressure		**8.9**	**0.3**
20	Force due to Surcharge Pressure - Operating Liquid		**83**	**0**
21	Force due to Surcharge Pressure - Test Liquid		**86.8**	**0**
22	Force due to Base Plate Pressure		**0**	**0**
23	Force due to Floating Roof Pressure		**0**	**0**
24	Force due to Live Load Pressure		**0.3**	**0**
25	Force due to Snow Load Pressure		**0.4**	**0**
26	Force due to Bearing Pressure	*** Refer Bearing Pressure Force Table**		

Note 1 : *The Vertical Rectangular Section of Ring Foundation alone is considered for the Torsion and Hoop Tension Resistance*

2.9.3 Bearing Pressure Force Calculation

Sl No.	Force due to Bearing Pressure (kN/m) (Area of Pressure Component)	CG of Pressure Force (m)	Eccentricity of Pressure Force (m) (W_w / 2 + W_{fi} - CG)
ULS1	**294.1**	**1**	**0**
ULS2	**302.6**	**1**	**0**
ULS3	**64.7**	**0.9**	**0**
ULS4	**95.7**	**0.9**	**0**
ULS5	**197.2**	**0.9**	**0**
ULS6	**281.2**	**0.9**	**0**
ULS7	**294.8**	**1**	**0**
ULS8	**295.1**	**1**	**0**
ULS9	**108.9**	**1**	**0**
ULS10	**109**	**1**	**0**
ULS11	**184.3**	**0.9**	**0**
ULS12	**268.4**	**0.9**	**0**

2.9.4 Forces and Moments acting on Ring Beam

Hoop Tension $$T_h = \Sigma(RadialForces) * \frac{D_i}{2}$$

Ring Beam Tension Capacity $$T_{rf}$$

Twisting Moment $$M_t = \Sigma(TorsionalMomentComponent)$$

Equivalent Bending Moment $$M_e = M_t * \left(\frac{D_i}{2} - W_{wf} + \frac{W_w}{2}\right)$$

Ring Beam Moment Capacity $$M_{re}$$

Sl No.	Ring Beam / Footing				
	Forces and Moments for Circumferential Reinforcement Design				
	T_h (kN)	T_{rf} (kN)	M_t (kN.m/m)	M_e (kN.m)	M_{re} (kN.m)
ULS1	**1286.7**	**8536.9**	**102.4**	**1024.1**	**5510.7**
ULS2	**1339.8**	**8536.9**	**106.6**	**1066.4**	**5475.9**
ULS3	**89.4**	**8536.9**	**9.3**	**93.4**	**6235.4**
ULS4	**125.1**	**8536.9**	**12.2**	**121.7**	**6214.5**
ULS5	**919.1**	**8536.9**	**75.4**	**754.1**	**5740.1**
ULS6	**1286.7**	**8536.9**	**104.7**	**1046.8**	**5510.7**
ULS7	**1291.1**	**8536.9**	**102.8**	**1027.6**	**5507.8**
ULS8	**1292.5**	**8536.9**	**102.9**	**1028.7**	**5506.9**

ULS9	126.8	8536.9	10	100.4	6213.5
ULS10	127.3	8536.9	10.1	100.8	6213.2
ULS11	969.6	8536.9	77.7	776.8	5709.4
ULS12	1338	8536.9	107	1069.9	5477

2.9.5 Unbalanced Moment on Ring Beam

Sl No.	Unbalanced Moment for Vertical Reinforcement Design	
	Unbalanced Moment (kN.m/m)	Moment Capacity (kN.m/m)
ULS1	78.1	669.9
ULS2	81.4	669.9
ULS3	4.2	669.9
ULS4	6	669.9
ULS5	55.4	669.9
ULS6	77.7	669.9
ULS7	78.7	669.9
ULS8	78.1	669.9
ULS9	6.6	669.9
ULS10	6.4	669.9
ULS11	58.1	669.9
ULS12	80.5	669.9

2.10 Footing Design

2.10.1 Forces / Moments acting on Footing Top

Sl No.	Forces / Moments for Top Rebar				
	Moment (kN.m/m)	Moment Capacity (kN.m/m)	Shear Force (kN/m)	Design Stress (N/mm²)	Strength (N/mm²)
ULS1	12.3	696.6	6.1	0.014	0.691
ULS2	12.9	696.6	6.4	0.015	0.691
ULS3	0	696.6	0	0	0.661
ULS4	0	696.6	0	0	0.661
ULS5	9.5	696.6	4.8	0.011	0.691
ULS6	13	696.6	6.5	0.015	0.691
ULS7	12.4	696.6	6.2	0.014	0.691
ULS8	12.2	696.6	6.1	0.014	0.691
ULS9	0	696.6	0	0	0.661
ULS10	0	696.6	0	0	0.661
ULS11	11.4	696.6	5.7	0.013	0.691
ULS12	14.9	696.6	7.5	0.017	0.691

2.10.2 Forces / Moments acting on Footing Bottom

Sl No.	Forces / Moments for Bottom Rebar				
	Moment (kN.m/m)	Moment Capacity (kN.m/m)	Shear Force (kN/m)	Design Stress (N/mm²)	Strength (N/mm²)
ULS1	15.6	827.6	7.8	0.018	0.735
ULS2	16.2	827.6	8.1	0.019	0.735
ULS3	3.4	827.6	1.7	0.004	0.735
ULS4	4.3	827.6	2.2	0.005	0.735
ULS5	12.1	827.6	6	0.014	0.735
ULS6	16.5	827.6	8.3	0.019	0.735
ULS7	15.7	827.6	7.8	0.018	0.735
ULS8	15.7	827.6	7.8	0.018	0.735

ULS9	**3.4**	**827.6**	**1.7**	**0.004**	**0.735**
ULS10	**3.5**	**827.6**	**1.7**	**0.004**	**0.735**
ULS11	**13**	**827.6**	**6.5**	**0.015**	**0.735**
ULS12	**17.5**	**827.6**	**8.7**	**0.02**	**0.735**

3.0 SUMMARY

3.1 Stability Checks

Condition	Combination	Actual	Allowable	Status
FOS Uplift	**SLS 3**	**4.92**	**1.2**	**PASS**
FOS Uplift - CLC	**CLC 3**	**4.92**	**1**	**PASS**
FOS Sliding	**SLS 3**	**16.26**	**1.5**	**PASS**
FOS Overturning	**SLS 3**	**18.25**	**1.5**	**PASS**
Bearing Pressure under Fdn (kN/m²)	**SLS 6**	**110.9**	**218.5**	**PASS**
Bearing Pressure under Tank (kN/m²)	**SLS 6**	**178.6**	**218.5**	**PASS**

3.2 Immediate Settlement

Condition	Combination	Actual	Allowable	Status
Max. Differential Settlement (mm)	**SLS 2**	**8.8**	**12**	**PASS**

3.3 Anchor Bolt

3.3.1 Bolt Anchorage Check

Description	Combination	Actual	Capacity	Status
Tension (kN)	**ULS 1**	**0**	**22.4**	**PASS**
Tension - CLC (kN)	**CLC 1**	**0**	**22.4**	**PASS**
Shear(kN)	**ULS 11**	**23.3**	**35.9**	**PASS**
Shear - CLC (kN)	**CLC 1**	**8.3**	**35.9**	**PASS**

3.3.2 Anchorage Interaction in Tension and Shear

Description	Combination	Actual Tension (kN)	Tension Capacity (kN)	Actual Shear (kN)	Shear Capacity (kN)	Interaction	Status
Interaction	**ULS 11**	**0**	**43.1**	**23.3**	**35.9**	**0.65**	**PASS**
Interaction - CLC	**CLC 1**	**0**	**43.1**	**8.3**	**35.9**	**0.232**	**PASS**

3.4 Ring Beam Design

3.4.1 Ring Beam Minimum Reinforcement

Position	Actual	Allowable	Status
Vertical Reinforcement Percentage (%)	**0.21**	**0.15**	**PASS**
Vertical Reinforcement Spacing (mm)	**120**	**400**	**PASS**
Longitudinal Reinforcement Percentage (%)	**1.28**	**0.25**	**PASS**
Side Bar Dia (mm)	**25**	**12**	**PASS**

3.4.2 Ring Beam Capacity

Condition	Combination	Required	Capacity	Status
Hoop Tension (kN)	**ULS 2**	**1339.8**	**8536.9**	**PASS**

Equivalent Bending Moment (kN.m)	**ULS 12**	**1069.9**	**5477**	**PASS**
Unbalanced Moment (kN.m/m)	**ULS 2**	**81.4**	**669.9**	**PASS**

3.5 Footing Design

3.5.1 Footing Minimum Reinforcement

Position	Provided	Min.Percentange	Max Spacing	Status
Top - Main	**25Φ at 120 c/c 0.82%**	**0.13%**	**300**	**PASS**
Bottom - Main	**25Φ at 100 c/c 0.98%**	**0.13%**	**300**	**PASS**
Top - Secondary	**12Φ at 150 c/c 0.15%**	**0.13%**	**300**	**PASS**
Bottom - Secondary	**12Φ at 150 c/c 0.15%**	**0.13%**	**300**	**PASS**

3.5.2 Footing Capacity

Position	Combination	Required	Capacity	Status
Top Moment (kN.m/m)	**ULS 12**	**14.9**	**696.6**	**PASS**
Bottom Moment (kN.m/m)	**ULS 12**	**17.5**	**827.6**	**PASS**
Top - Shear Resistance (kN/m)	**ULS 12**	**7.5**	**302.5**	**PASS**
Bottom - Shear Resistance (kN/m)	**ULS 12**	**8.7**	**321.4**	**PASS**