PRCA20240398

City of Puyallup
Development & Permitting Services
ISSUED PERMIT
Building | Planning
Engineering | Public Works
Fire | Traffic

COASTAL PACIFIC FOOD DISTRIBUTORS

FIRE WATER STORAGE TANK – FOUNDATIONS

STRUCTURAL CALCULATIONS

Prepared By:
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Reviewed by
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STATE OF WASHINGTON
23017421
REGISTERED
PROFESSIONAL ENGINEER
28 JUN 2024

AWB Engineers
1942 Northwood Drive
Salisbury, Maryland 21801

Date:

June 27, 2024

City of Puyallup
Building
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CITY OF PUYALLUP
STATE OF WASHINGTON

Calculations required to be provided by the Permittee on site for all Inspections

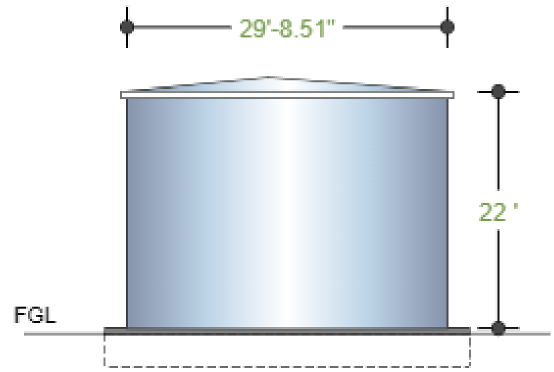
ECTANK Storage Tank Foundation Design **Job :** 221205 - Fire Tank - 2

Licensed to: Vivek kannan **Powered By:** ECPlus www.ecplusdesign.com

1.0 INPUT

1.1 Design Options

AWWAD100: 221205 - CPFD - Fire Tank



Tank No	**221205 - CPFD - Fire Tank**
Foundation Type	**Soil Supported**
Tank Type	**AWWA D100**
Design Standard	**American Standard**
Unit	**English Unit**

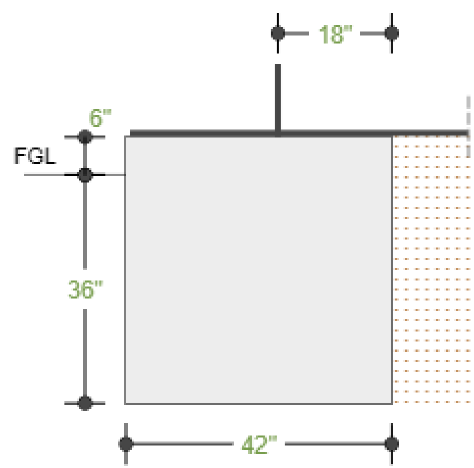
1.2 Tank Data

Roof Type			**Fixed**
Tank Inner Diameter	D_i	=	**356.51** in
Shell Height	H_t	=	**264** in
Roof Height	H_r	=	**15** in
Corrosion Allowance	C_{af}	=	**1** %

1.2.1 Internal Pressure

Design Pressure	G_{design}	=	**0** ksf
Operating Pressure	G_{oper}	=	**0** ksf
Test Pressure	G_{test}	=	**0** ksf
External (Vacuum) Pressure	$G_{external}$	=	**0** ksf

1.3 Foundation Data



RING BEAM FOUNDATION

Depth of Foundation	D_f	=	**36** in
Height of Ring Beam above Ground	H_{ag}	=	**6** in
Width of Ring Beam	W_w	=	**42** in
Width in Contact with Fluid	W_{wf}	=	**18** in

1.4 Grade Slab

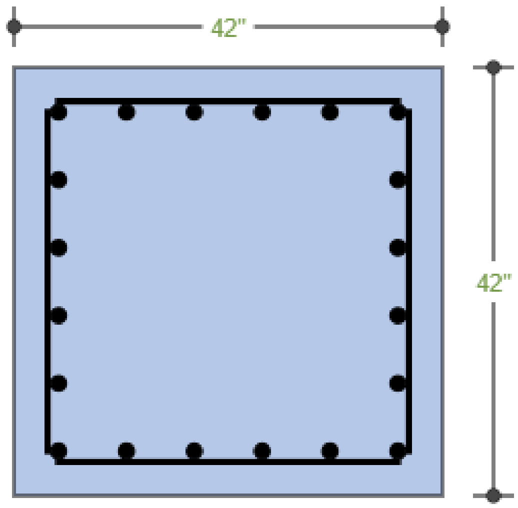
Grade Slab	**None**

1.5 Rebars and Anchor Bolt

1.5.1 Reinforcement

Clear Cover for Ring Beam	C_{rb}	=	**3** in

<u>Ring Beam Reinforcement</u>



and Bottom Layers (1): 6 - #6 each.
rmediate Layers (2): 4 - #6 each. Total:8.8 in² (0.5%)
ical: #5 - 9" c/c (0.8 in²/ft - 0.16%)

1.6 Soil

Allowable Increase of SBC for Test	SBC_t	=	**0** %
Allowable Increase of SBC for Wind	SBC_w	=	**0** %
Allowable Increase of SBC for Seismic	SBC_s	=	**0** %
Allowable Safe Bearing Pressure	SBC	=	**3** ksf
Unit Weight of Soil	γ_{soil}	=	**120** pcf
Angle of Internal Friction	Φ	=	**30** deg
Pressure Coefficient Type	K	=	**Active (ka)**
Co-efficient of Friction	μ	=	**0.35**
Poisson's Ratio	ν	=	**0.35**
Soil Elasticity Modulus	E_{so}	=	**750** ksf
Hard Stratum Depth for Settlement	H_{sd}	=	**200** in
Allowable Differential Settlement	δ_{allow}	=	**0.5** in
Ground Water Depth	H_{wt}	=	**120** in
Density of Ground Water	γ_w	=	**65** pcf

1.7 Reinforced Concrete Properties

Concrete Type		=	**Normal Weight**
Density of Steel	γ_{steel}	=	**490** pcf

Density of Concrete	γ_{conc}	=	**150** pcf
Compressive Strength of Concrete	f'_c	=	**3** ksi
Yield Strength of Reinforcement	f_y	=	**60** ksi
Concrete Modification Factor	λ	=	**1**
Modulus of Elasticity of Steel	E_s	=	**29000** ksi

1.8 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**

1.9 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
Gdesign	Design Internal Pressure
Goper	Operating Internal Pressure
Gtest	Test Internal Pressure
Gexternal	External Pressure

1.10 Loads Data

1.10.1 Tank Loads

Description	Axial Load (Kips)	Shear at Tank Base (Kips)	Moment at Tank Base (Kips.ft)
Empty Weight (De)	20.7		
Tank Bottom Plate Weight (Dbp)	3.5		
Floating Roof Weight (Drs)	0.0		
Operating Weight (Do)	776.0		
Test Weight (Dt)	776.0		
Live Load (L)	12.0		
Snow Load (S)	10.0		
Wind Load (W)	5.0	12.0	130.0

1.10.1 Tank Loads

Description	Axial Load (Kips)	Shear at Tank Base (Kips)	Moment at Tank Base (Kips.ft)
Seismic Load - Ring Beam Component (Vs, Mrw)		180.0	1281.0
Seismic Load - Slab Component (Ms)			1281.0

1.11 Load Combination

1.11.1 Serviceability Load Combinations

No	Combination
SLS1	Ds + Do + Gdesign
SLS2	Ds + Dt + Gtest
SLS3	Ds + De + WL + 0.4Gdesign
SLS4	Ds + De + WL + Goper
SLS5	Ds + Do + WL + 0.4Gdesign
SLS6	Ds + Do + WL + Goper
SLS7	Ds + De + WL + 0.4Gexternal
SLS8	Ds + Do + WL + 0.4Gexternal
SLS9	Ds + Do + L + 0.4Gexternal
SLS10	Ds + Do + S + 0.4Gexternal
SLS11	Ds + De + 0.4L + Gexternal
SLS12	Ds + De + 0.4S + Gexternal
SLS13	Ds + Do + 0.4L + Gexternal
SLS14	Ds + Do + 0.4S + Gexternal
SLS15	Ds + Do + 0.1S + Eo + 0.4Gdesign
SLS16	Ds + Do + 0.1S + Eo + Goper

1.11.2 Ultimate Load Combinations

No	Combination
ULS1	1.4Ds + 1.4Do + 1.4Gdesign
ULS2	1.4Ds + 1.4Dt + 1.4Gtest
ULS3	0.9Ds + 0.9De + 1.6WL + 0.4Gdesign
ULS4	1.2Ds + 1.2De + 1.6WL + 0.5Gdesign
ULS5	0.9Ds + 0.9De + 1.6WL + 0.9Goper
ULS6	1.2Ds + 1.2De + 1.6WL + 1.2Goper
ULS7	0.9Ds + 0.9Do + 1.6WL + 0.4Gdesign
ULS8	1.2Ds + 1.2Do + 1.6WL + 0.5Gdesign

1.11.2 Ultimate Load Combinations

No	Combination
ULS9	0.9Ds + 0.9Do + 1.6WL + 0.9Goper
ULS10	1.2Ds + 1.2Do + 1.6WL + 1.2Goper
ULS11	0.9Ds + 0.9De + 1.6WL + 0.4Gexternal
ULS12	1.2Ds + 1.2De + 1.6WL + 0.5Gexternal
ULS13	0.9Ds + 0.9Do + 1.6WL + 0.4Gexternal
ULS14	1.2Ds + 1.2Do + 1.6WL + 0.5Gexternal
ULS15	0.9Ds + 0.9Do + 0.8WL + 0.4Gexternal
ULS16	1.2Ds + 1.2Do + 1.6L + 0.8WL + 0.5Gexternal
ULS17	1.2Ds + 1.2Do + 1.6S + 0.8WL + 0.5Gexternal
ULS18	0.9Ds + 0.9De + 1.6WL + 0.9Gexternal
ULS19	1.2Ds + 1.2De + 0.6L + 1.6WL + 1.2Gexternal
ULS20	1.2Ds + 1.2De + 0.6S + 1.6WL + 1.2Gexternal
ULS21	0.9Ds + 0.9Do + 1.4Eo + 0.4Gdesign
ULS22	1.2Ds + 1.2Do + 0.2S + 1.4Eo + 0.5Gdesign
ULS23	0.9Ds + 0.9Do + 1.4Eo + 0.9Goper
ULS24	1.2Ds + 1.2Do + 0.2S + 1.4Eo + 1.2Goper

1.11.3 Additional Load Combinations

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

2.0 OUTPUT

2.1 Geometry of Tank Foundation

Inner Diameter of Ring Beam $D_{i_r} = D_i - 2 * W_{wf}$ **26.7** ft

Outer Diameter of Ring Beam $D_{o_r} = D_{i_r} + 2 * W_w$ **33.7** ft

Overall Depth of Ring Beam $H_{rb} = D_f + H_{ag}$ **3.5** ft

2.2 Properties of Tank Foundation

Base Area of Ring Beam $A_r = \frac{\pi}{4} * \left({D_{o_r}}^2 - {D_{i_r}}^2 \right)$ **332.2** ft^2

Surface Area of Soil Enclosed by Ring Beam $A_{s_r} = \frac{\pi * {D_{i_r}}^2}{4}$ **560.3** ft^2

Section Modulus of Ring Beam	$S_r = \frac{\pi * \left(D_{o_r}^4 - D_{i_r}^4\right)}{32 * D_{o_r}}$	**2278.3** ft^3

2.3 Load Calculation

[Tank Loads provided by the User / Vendor]

Cross Section Area of Tank	$A_t = \frac{\pi * D_i^2}{4}$	**693.2** ft^2
Surface Area of Roof	$A_{r_o} = \pi * \frac{D_i}{2} * \sqrt{\left(\frac{D_i}{2}\right)^2 + H_r^2}$	**695.7** ft^2
Self-Weight of Ring Beam	$W_{r_b} = A_r * H_{r_b} * \gamma_{con_c}$	**174.4** Kips
Weight of Soil Interior to Foundation	$W_{s_f} = A_{s_r} * H_{r_b} * \gamma_{soi_l}$	**235.3** Kips
Self-Weight of Shell	$W_{s_p} = W_e - D_{b_p}$	**17.2** Kips
% of Tank Content Load to Ring Beam	$R_w = \frac{A_t - A_{s_r}}{A_t} * 100$	**19.2** %
Tank Base Plate Load to Ring Beam	$W_{t_r} = D_{b_p} * R_w$	**0.7** Kips
Remaining Tank Base Plate Load	$D_{b_{p_f}} = D_{b_p} - W_{t_r}$	**2.8** Kips
Floating Roof Load to Ring Beam	$W_{r_r} = D_{r_s} * R_w$	**0** Kips
Design Floating Roof Load	$D_{f_r} = W_{r_r}$	**0** Kips
Remaining Floating Roof Load	$D_{r_{s_f}} = D_{r_s} - D_{f_r}$	**0** Kips
Design Live Load	$D_{L_l} = L$	**12** Kips
Design Snow Load	$D_{s_l} = S$	**10** Kips
Shell Knife Edge Load	$W_{s_k} = W_e - D_{b_p}$	**17.2** Kips
Empty Weight to Ring Beam	$W_{e_t} = W_{s_k} + W_{t_r}$	**17.9** Kips
Operating Content Load to Ring Beam	$W_{o_t} = \left(D_o - D_e\right) * R_w$	**144.8** Kips
Remaining Operating Content Weight	$W_{o_{t_f}} = D_o - D_e - W_{o_t}$	**610.5** Kips
Testing Content Load to Ring Beam	$W_{t_t} = \left(D_t - D_e\right) * R_w$	**144.8** Kips
Remaining Test Content Weight	$W_{t_{t_f}} = D_t - D_e - W_{t_t}$	**610.5** Kips

2.4 Buoyancy Load

Buoyancy Load **0** Kips

2.5 Loads on Foundation

Sl.No	Load Case	On Top of Foundation			
		Axial (Kips)		Shear (Kips)	Moment (Kips.ft)
1	Dc - Dead (Self) Weight of Concrete = W_{rb}	**174.4**			
2	Ds - Dead (Self) Weight of Soil	**0.0**	**235.3** *		
3	BL - Buoyancy Load = B_L	**0.0**			
4	De - Dead (Empty / Self) Weight of Tank = W_{et}	**17.9**	**2.8** *		
5	Drs - Floating Roof Weight	**0.0**	**0.0** *		
6	Do - Equipment Operating Content Weight = W_{ot}	**144.8**	**610.5** *		
7	Dt - Equipment Test Content Weight = W_{tt}	**144.8**	**610.5** *		
8	L - Live Load	**12.0**			
9	S - Snow Load	**10.0**			
10	WL - Wind Load	**5.0**		**12.0**	**130.0**
11	Eo - Seismic Load Ring Beam Component			**180.0**	**1281.0**
12	Eo - Seismic Load Slab Component				**1281.0**

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

2.6 Service Loads on Foundation

SLS Comb	Total Vertical Load (max) (Kips)	Total Vertical Load (min) (Kips)	Total Shear (Kips)	Total Moment (Kips.ft)
SLS1	337.1	336.9	0.0	0.0
SLS2	337.1	336.9	0.0	0.0
SLS3	192.2	192.1	12.0	172.0
SLS4	192.2	192.1	12.0	172.0
SLS5	337.1	336.9	12.0	172.0
SLS6	337.1	336.9	12.0	172.0
SLS7	192.2	192.1	12.0	172.0
SLS8	337.1	336.9	12.0	172.0
SLS9	349.1	348.9	0.0	0.0
SLS10	347.1	346.9	0.0	0.0
SLS11	197.0	196.9	0.0	0.0

SLS Comb	Total Vertical Load (max) (Kips)	Total Vertical Load (min) (Kips)	Total Shear (Kips)	Total Moment (Kips.ft)
SLS12	196.2	196.1	0.0	0.0
SLS13	341.9	341.7	0.0	0.0
SLS14	341.1	340.9	0.0	0.0
SLS15	338.1	337.9	180.0	1911.0
SLS16	338.1	337.9	180.0	1911.0

Note : *Total Vertical Load (max) - Maximum load condition with no reductions.*
Total Vertical Load (min) - Considers buoyancy and corrosion reduction.

2.7 Stability Checks

2.7.1 Uplift Check

Sl.No	Downward Force (Kips) Vertical Load	Upward Force (Kips)	FOS	Status
SLS1	**336.9**	**0.0**	**100.00**	**OK**
SLS2	**336.9**	**0.0**	**100.00**	**OK**
SLS3	**192.1**	**0.0**	**100.00**	**OK**
SLS4	**192.1**	**0.0**	**100.00**	**OK**
SLS5	**336.9**	**0.0**	**100.00**	**OK**
SLS6	**336.9**	**0.0**	**100.00**	**OK**
SLS7	**192.1**	**0.0**	**100.00**	**OK**
SLS8	**336.9**	**0.0**	**100.00**	**OK**
SLS9	**348.9**	**0.0**	**100.00**	**OK**
SLS10	**346.9**	**0.0**	**100.00**	**OK**
SLS11	**196.9**	**0.0**	**100.00**	**OK**
SLS12	**196.1**	**0.0**	**100.00**	**OK**
SLS13	**341.7**	**0.0**	**100.00**	**OK**
SLS14	**340.9**	**0.0**	**100.00**	**OK**
SLS15	**337.9**	**0.0**	**100.00**	**OK**
SLS16	**337.9**	**0.0**	**100.00**	**OK**

2.7.2 Check for Sliding

Sl.No	Resisting Force (Kips) Vertical Load * µ	Sliding Force (Kips) (Hor. Shear Force)	FOS	Status
SLS1	**414.9**	**0.0**	**100.00**	**OK**
SLS2	**414.9**	**0.0**	**100.00**	**OK**

SLS3	**150.6**	**12.0**	**12.55**	**OK**
SLS4	**150.6**	**12.0**	**12.55**	**OK**
SLS5	**414.9**	**12.0**	**34.58**	**OK**
SLS6	**414.9**	**12.0**	**34.58**	**OK**
SLS7	**150.6**	**12.0**	**12.55**	**OK**
SLS8	**414.9**	**12.0**	**34.58**	**OK**
SLS9	**419.1**	**0.0**	**100.00**	**OK**
SLS10	**418.4**	**0.0**	**100.00**	**OK**
SLS11	**152.2**	**0.0**	**100.00**	**OK**
SLS12	**152.0**	**0.0**	**100.00**	**OK**
SLS13	**416.6**	**0.0**	**100.00**	**OK**
SLS14	**416.3**	**0.0**	**100.00**	**OK**
SLS15	**415.3**	**180.0**	**2.31**	**OK**
SLS16	**415.3**	**180.0**	**2.31**	**OK**

2.7.3 Check for Overturning

Distance from Center to Edge of Ring Beam B_r **16.85** ft

Sl.No	**Resisting Moment (Kips.ft)** (Vertical Load * B_r)	**Overturning Moment (Kips.ft)** (Hor. Moments)	**FOS**	**Status**
SLS1	**5678.4**	**0.0**	**100.00**	**OK**
SLS2	**5678.4**	**0.0**	**100.00**	**OK**
SLS3	**3237.2**	**172.0**	**18.82**	**OK**
SLS4	**3237.2**	**172.0**	**18.82**	**OK**
SLS5	**5678.4**	**172.0**	**33.01**	**OK**
SLS6	**5678.4**	**172.0**	**33.01**	**OK**
SLS7	**3237.2**	**172.0**	**18.82**	**OK**
SLS8	**5678.4**	**172.0**	**33.01**	**OK**
SLS9	**5880.7**	**0.0**	**100.00**	**OK**
SLS10	**5847.0**	**0.0**	**100.00**	**OK**
SLS11	**3318.1**	**0.0**	**100.00**	**OK**
SLS12	**3304.7**	**0.0**	**100.00**	**OK**
SLS13	**5759.3**	**0.0**	**100.00**	**OK**
SLS14	**5745.8**	**0.0**	**100.00**	**OK**
SLS15	**5695.3**	**1911.0**	**2.98**	**OK**
SLS16	**5695.3**	**1911.0**	**2.98**	**OK**

2.7.4 Check for Bearing Pressure

Sl.No	Base Pressure Under Tank (ksf)	Base Pressure Under Tank at Fdn. Level (ksf)	Max. Base Pressure Under Ring Beam / Footing (ksf)	Min. Base Pressure Under Ring Beam / Footing (ksf)	Contact %	Allowable Base Pressure (ksf)	Status
SLS1	**1.09**	**1.51**	**1.01**	**1.01**	**100.00**	**3.36**	**OK**
SLS2	**1.09**	**1.51**	**1.01**	**1.01**	**100.00**	**3.36**	**OK**
SLS3	**0.01**	**0.43**	**0.65**	**0.50**	**100.00**	**3.36**	**OK**
SLS4	**0.01**	**0.43**	**0.65**	**0.50**	**100.00**	**3.36**	**OK**
SLS5	**1.09**	**1.51**	**1.09**	**0.94**	**100.00**	**3.36**	**OK**
SLS6	**1.09**	**1.51**	**1.09**	**0.94**	**100.00**	**3.36**	**OK**
SLS7	**0.01**	**0.43**	**0.65**	**0.50**	**100.00**	**3.36**	**OK**
SLS8	**1.09**	**1.51**	**1.09**	**0.94**	**100.00**	**3.36**	**OK**
SLS9	**1.09**	**1.51**	**1.05**	**1.05**	**100.00**	**3.36**	**OK**
SLS10	**1.09**	**1.51**	**1.04**	**1.04**	**100.00**	**3.36**	**OK**
SLS11	**0.01**	**0.43**	**0.59**	**NA**	**100.00**	**3.36**	**OK**
SLS12	**0.01**	**0.43**	**0.59**	**0.59**	**100.00**	**3.36**	**OK**
SLS13	**1.09**	**1.51**	**1.03**	**NA**	**100.00**	**3.36**	**OK**
SLS14	**1.09**	**1.51**	**1.03**	**1.03**	**100.00**	**3.36**	**OK**
SLS15	**1.59**	**2.01**	**1.86**	**0.18**	**100.00**	**3.36**	**OK**
SLS16	**1.59**	**2.01**	**1.86**	**0.18**	**100.00**	**3.36**	**OK**

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

Note 2 : *The allowable gross bearing pressure = SBC * (1 + (SBC Inc %)/100) +* γ_{soil} * D_f

2.8 Immediate Settlement Calculation

Ref: Foundation Analysis and Design - Bowles

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

Hard Stratum Depth	$H = H_{sd}$	**200** ft
Foundation Depth	$D = D_f$	**36** ft

2.8.1 Under Tank Near Footing

Foundation Breadth	$B_c = \sqrt{\frac{\pi * D_i * D_i}{4}}$	**26.3** ft
Foundation Length	$L_c = \sqrt{\frac{\pi * D_i * D_i}{4}}$	**26.3** ft
Length by Breadth Ratio	$\frac{L_c}{B_c}$	**1**

Depth by Breadth Ratio	$\frac{D}{B_c}$	**0.1**
Influence Factor	I_{fc}	**0.794**
	$B' = B_c$	**26.3** ft
	$L' = L_c$	**26.3** ft
Ratio 1	$M = \frac{L'}{B'}$	**1**
Ratio 2	$N = \frac{H}{B'}$	**0.6**

$$I_1 = \frac{1}{\pi} * \left(M * \left(ln\left(\frac{\left(1+\sqrt{M^2+1}\right) * \sqrt{M^2+N^2}}{M * \left(1+\sqrt{M^2+N^2+1}\right)} \right) \right) + ln\left(\frac{\left(M+\sqrt{M^2+1}\right) * \sqrt{1+N^2}}{M + \left(\sqrt{M^2+N^2+1}\right)} \right) \right)$$ **0.073**

$$I_2 = \frac{N}{2 * \pi} * tan^{-1}\left(\frac{M}{N * \sqrt{M^2+N^2+1}} \right)$$ **0.08**

Influence Factor 2	$I_s = I_1 + \frac{1-2*\mu}{1-\mu} * I_2$	**0.11**
No of Corners for Edge	m	**1**
Max. Bearing Pressure Under Tank	M_{bp_c}	
Settlement near Footing	$\delta h_c = M_{bp_c} * B' * \frac{1-\mu^2}{E_{so}} * m * I_s * I_{fc}$	

2.8.2 Under Footing

Length by Breadth Ratio	$\frac{\pi * D_i}{W_w}$	**26.7**
Depth by Breadth Ratio	$\frac{D}{W_w}$	**0.9**
Influence Factor	I_{fe}	**0.819**
	$B'' = \frac{W_w}{2}$	**1.8** ft
	$L'' = \frac{\pi * D_i}{2}$	**46.7** ft
Ratio 3	$M'' = \frac{L''}{B''}$	**26.7**
Ratio 4	$N'' = \frac{H}{B''}$	**9.5**

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

0.728

$$I_2'' = \frac{N''}{2*\pi} * tan-1\left(\frac{M''}{N'' * \sqrt{M''^2+N''^2+1}} \right)$$ **0.149**

Influence Factor 3 $I_s'' = I_1'' + \left(\frac{1-2*\mu}{1-\mu}\right) * I_2''$ **0.797**

No of Corners m'' **4**

Max. Bearing Pressure under Footing M_{bp_e}

Settlement under Footing $\delta h_e = M_{bp_e} * B'' * \frac{1-\mu^2}{E_{so}} * m'' * I_s'' * I_{fe}$

Differential Settlement $\delta h = \delta h_c - \delta h_e$

Sl No.	δh_c (in)	δh_e (in)	δh (in)	δh_{allow} (in)	Status
SLS1	**0.0**	**0.1**	**0.0**	**0.5**	**Safe**
SLS2	**0.0**	**0.1**	**0.0**	**0.5**	**Safe**
SLS9	**0.0**	**0.1**	**0.0**	**0.5**	**Safe**
SLS10	**0.0**	**0.1**	**0.0**	**0.5**	**Safe**
SLS11	**0.0**	**0.0**	**0.0**	**0.5**	**Safe**
SLS12	**0.0**	**0.0**	**0.0**	**0.5**	**Safe**
SLS13	**0.0**	**0.1**	**0.0**	**0.5**	**Safe**
SLS14	**0.0**	**0.1**	**0.0**	**0.5**	**Safe**

Note : *Wind and Seismic Combinations not included.*

2.9 Ring Beam Design

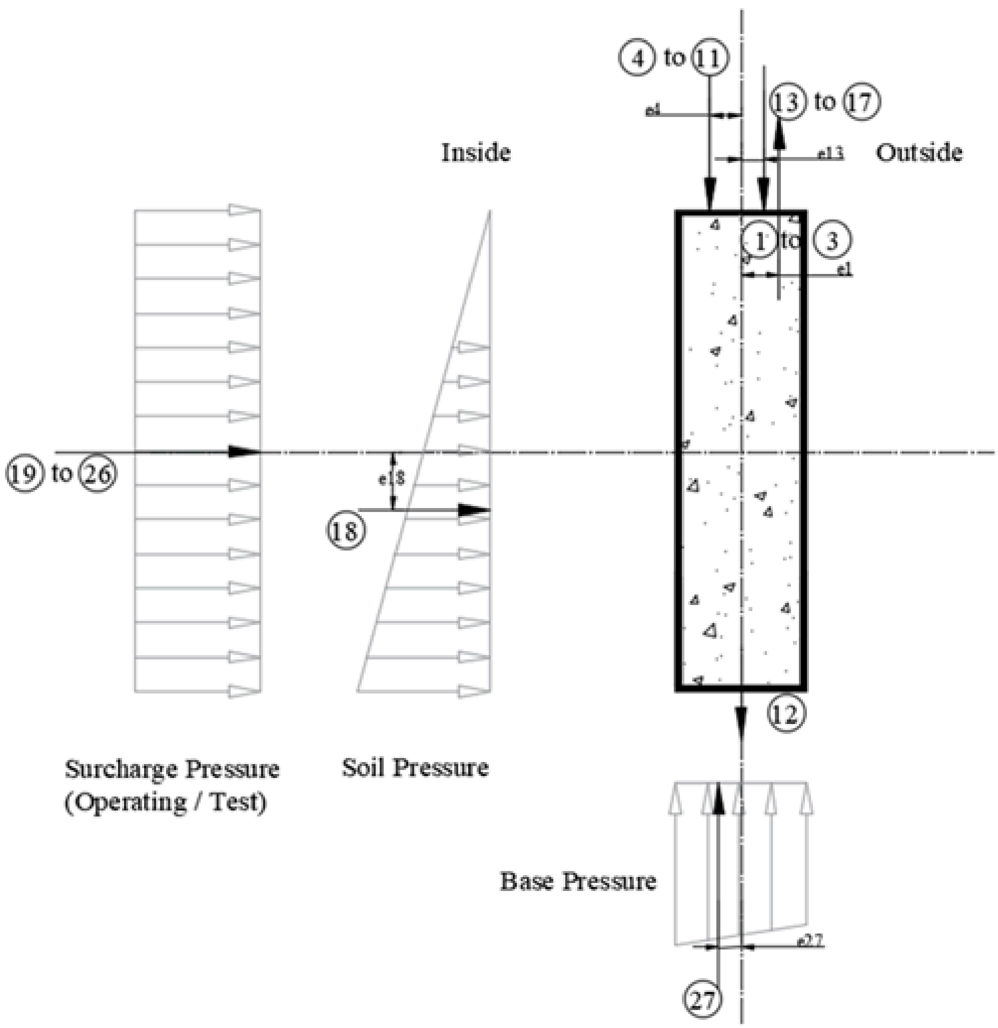
2.9.1 Design of Circumferential Reinforcement for Ring Beam

Active Earth Pressure Coefficient $k = \frac{1-Sin(\Phi)}{1+Sin(\Phi)}$ **0.33**

Radial Force due to Soil Pressure $F_{soil} = 0.5 * k * \gamma_{soil} * H_{rb}^2$ **0.24** kips/ft

Radial Force due to Operating Surcharge	$F_{op_{er}} = k * \frac{D_o - D_e}{A_t} * H_{rb}$	**1.27** kips/ft
Radial Force due to Test Surcharge	$F_{tes_t} = k * \frac{D_t - D_e}{A_t} * H_{rb}$	**1.27** kips/ft
Radial Force due to Base Plate	$F_{pl_{ate}} = k * \frac{D_{bp} - W_{tr}}{A_{sr}} * H_{rb}$	**0** kips/ft
Radial Force due to Floating Roof	$F_{roof} = k * \frac{D_{rs} - W_{fr}}{A_{sr}} * H_{rb}$	**0** kips/ft
Radial Force due to Sloshing Pressure	$F_{slos_h} = k * \frac{M_s}{\frac{\pi}{32} * D_i^3} * H_{rb}$	**0.5** kips/ft

2.9.2 Check for Torsion



Sl No.	Torsion Components	Vertical Forces (kips/ft)	Horizontal Forces (kips/ft)	Eccentricity (ft)

1	Shell Edge Load	**0.2**		**0.2**
2	Live Load	**0.1**		**0.2**
3	Snow Load	**0.1**		**0.2**
4	Base Plate Load on Ring Beam	**0.0**		**1.0**
5	Floating Roof Weight on Ring Beam	**0.0**		**1.0**
6	Operating Liquid Load on Ring Beam	**1.6**		**1.0**
7	Test Liquid Load on Ring Beam	**1.6**		**1.0**
8	Design Pressure on Ring Beam	**0.0**		**1.0**
9	Operating Pressure on Ring Beam	**0.0**		**1.0**
10	Test Pressure on Ring Beam	**0.0**		**1.0**
11	External Pressure on Ring Beam	**0.0**		**1.0**
12	Self-Weight of Foundation	**1.8**		**0.0**
13	Uplift Force - Wind Load	**-0.2**		**-0.3**
14	Uplift Force - Seismic Load	**-1.7**		**-0.3**
15	Uplift Force - Design Internal Pressure	**0.0**		**-0.3**
16	Uplift Force - Operating Internal Pressure	**0.0**		**-0.3**
17	Uplift Force - Test Internal Pressure	**0.0**		**-0.3**
18	Force due to Soil Pressure		**0.2**	**0.6**
19	Force due to Surcharge Pressure - Operating Liquid		**1.3**	**0.0**
20	Force due to Surcharge Pressure - Test Liquid		**1.3**	**0.0**
21	Force due to Design Internal Pressure		**0.0**	**0.0**
22	Force due to Operating Internal Pressure		**0.0**	**0.0**
23	Force due to Test Internal Pressure		**0.0**	**0.0**
24	Force due to External Pressure		**0.0**	**0.0**
25	Force due to Base Plate Pressure		**0.0**	**0.0**
26	Force due to Floating Roof Pressure		**0.0**	**0.0**
27	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 (kips/ft)** (Area of Pressure Component)	**CG of Pressure Force (ft)**	**Eccentricity of Pressure Force (ft)** (W_w / 2 - CG)
ULS1	**5.0**	**1.8**	**0.0**
ULS2	**5.0**	**1.8**	**0.0**
ULS3	**1.4**	**1.7**	**0.0**
ULS4	**2.1**	**1.7**	**0.0**
ULS5	**1.4**	**1.7**	**0.0**

ULS6	**2.1**	**1.7**	**0.0**
ULS7	**2.8**	**1.7**	**0.0**
ULS8	**3.9**	**1.7**	**0.0**
ULS9	**2.8**	**1.7**	**0.0**
ULS10	**3.9**	**1.7**	**0.0**
ULS11	**1.4**	**1.7**	**0.0**
ULS12	**2.1**	**1.7**	**0.0**
ULS13	**2.8**	**1.7**	**0.0**
ULS14	**3.9**	**1.7**	**0.0**
ULS15	**3.0**	**1.7**	**0.0**
ULS16	**4.3**	**1.7**	**0.0**
ULS17	**4.2**	**1.7**	**0.0**
ULS18	**1.4**	**1.7**	**0.0**
ULS19	**2.1**	**1.7**	**0.0**
ULS20	**2.1**	**1.7**	**0.0**
ULS21	**0.0**	**0.0**	**1.8**
ULS22	**0.6**	**1.3**	**0.4**
ULS23	**0.0**	**0.0**	**1.8**
ULS24	**0.6**	**1.3**	**0.4**

2.9.4 Forces and Moments acting on Ring Beam

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

Ring Beam Tension Capacity T_{rf}

Twisting Moment $M_t = \sum \left(TorsionalMomentComponents * Eccentricity \right)$

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				
	Forces and Moments for Circumferential Reinforcement Design				
	T_h (Kips)	T_{rf} (Kips)	M_t (Kips.ft/ft)	M_e (Kips.ft)	M_{re} (Kips.ft)
ULS1	**31.7**	**477.1**	**2.6**	**38.7**	**693.0**
ULS2	**31.7**	**477.1**	**2.6**	**38.7**	**693.0**
ULS3	**3.4**	**477.1**	**0.2**	**3.3**	**734.1**
ULS4	**4.5**	**477.1**	**0.3**	**4.2**	**732.5**
ULS5	**3.4**	**477.1**	**0.2**	**3.3**	**734.1**
ULS6	**4.5**	**477.1**	**0.3**	**4.2**	**732.5**

ULS7	**20.3**	**477.1**	**1.7**	**25.6**	**709.5**
ULS8	**27.1**	**477.1**	**2.2**	**33.9**	**699.6**
ULS9	**20.3**	**477.1**	**1.7**	**25.6**	**709.5**
ULS10	**27.1**	**477.1**	**2.2**	**33.9**	**699.6**
ULS11	**3.4**	**477.1**	**0.2**	**3.3**	**734.1**
ULS12	**4.5**	**477.1**	**0.3**	**4.2**	**732.5**
ULS13	**20.3**	**477.1**	**1.7**	**25.6**	**709.5**
ULS14	**27.1**	**477.1**	**2.2**	**33.9**	**699.6**
ULS15	**20.3**	**477.1**	**1.7**	**25.2**	**709.5**
ULS16	**27.1**	**477.1**	**2.3**	**34.3**	**699.6**
ULS17	**27.1**	**477.1**	**2.3**	**34.2**	**699.6**
ULS18	**3.4**	**477.1**	**0.2**	**3.3**	**734.1**
ULS19	**4.5**	**477.1**	**0.3**	**4.5**	**732.5**
ULS20	**4.5**	**477.1**	**0.3**	**4.5**	**732.5**
ULS21	**32.4**	**477.1**	**2.3**	**34.0**	**691.9**
ULS22	**39.2**	**477.1**	**2.6**	**38.7**	**682.1**
ULS23	**32.4**	**477.1**	**2.3**	**34.0**	**691.9**
ULS24	**39.2**	**477.1**	**2.6**	**38.7**	**682.1**

3.0 SUMMARY

3.1 Stability Checks

Condition	Combination	Actual	Allowable	Status
FOS Uplift	**SLS 1**	**100.00**	**1.20**	**Pass**
FOS Sliding	**SLS 15**	**2.31**	**1.50**	**Pass**
FOS Overturning	**SLS 15**	**2.98**	**1.50**	**Pass**
Bearing Pressure under Fdn. (ksf)**	**SLS 15**	**1.86**	**3.36**	**Pass**
Bearing Pressure under Tank (ksf)**	**SLS 15**	**2.01**	**3.36**	**Pass**
** The allowable gross bearing pressure = SBC * (1 + (SBC Inc %)/100) + γ_{soil} * D_f				

3.2 Immediate Settlement

Condition	Combination	Actual	Allowable	Status
Max. Differential Settlement (in)	**SLS 11**	**0.0**	**0.5**	**Pass**

3.3 Ring Beam Design

3.3.1 Ring Beam Minimum Reinforcement

Position	Actual	Allowable	Status
Vertical Reinforcement Percentage (%)	**0.16**	**0.12**	**Pass**
Vertical Reinforcement Spacing (in)	**9.0**	**12.0**	**Pass**
Longitudinal Reinforcement Percentage (%)	**0.50**	**0.25**	**Pass**
Side Bar Spacing (in)	**6.6**	**8.4**	**Pass**
Main Bar Spacing (in)	**7.0**	**7.8**	**Pass**

Note: 1. The minimum reinforcement required is computed as per Table 11.6.1.

2. The maximum allowed spacing for Side rebar is computed as per Cl. 9.9.3 (b).

3. The maximum allowed spacing for Side and Main rebar is computed as per Cl. 24.3.2.

3.3.2 Ring Beam Capacity

Condition	Combination	Required	Capacity	Status
Hoop Tension (Kips)	**ULS 22**	**39.2**	**477.1**	**Pass**
Equivalent Bending Moment (Kips.ft)	**ULS 22**	**38.7**	**682.1**	**Pass**

Note: Hoop tension and equivalent bending due to torsion are resisted by the Hoop Reinforcement.