PT.HANAZONO Engineering Indonesia

COMO ENGINEERS

CPM PT Citra Palu Minerals

OBJECT

Strength Calculation for Filter Feed Tank
Poboya 2000tpd Expansion Project
Client Doc Number : HNZ-V-PT0061.08-4820-STR-CAL-004

REFERENCES

3655.15-61.08-4000-F-BOD-001Process Design Criteria
3655.15-61.08-4000-F-CAL-001Mass Balance

B	Issued for Approval	08/05/2026	Wawan	Ardiyanto	Muraasto	
A	Issued for Review	06/04/2026	Wawan	Ardiyanto	Muraasto	
Revision	Description	Date	Prepared By	Reviewed By	Approved	Client App

CLIENT: PT Citra Palu Mineral				TITLE: Strength Calculation for Filter Feed Tank	REV: B
PROJECT: Poboya 2000tpd Expansion Project				PT. COMO ENGINEERS	PROJECT No.: E2602
BY: Wawan	DATE: 08/05/2026	CHECKED: Ardiyanto	DATE: 08/05/2026		Doc No: E2602-4820-CAL-401

Revision History

REV. No.	DATE	DESCRIPTION	REVISION BY
A	April, 06, 2026	Issued for Review	
B	May, 08, 2026	Issued for Approval	

CONTENTS

1. Introduction

This document consist of additional analysis for tank thickness. The dimension is 9.3 m height and 8.5 m for the diameter. Additional analysis needed to calculate the strength of shell tank to resist equipment (agitator) load that located on top of the tank.

2. Support Document

- *MC5925_02- Filter Feed Tank Agitator*

3. Code and Reference

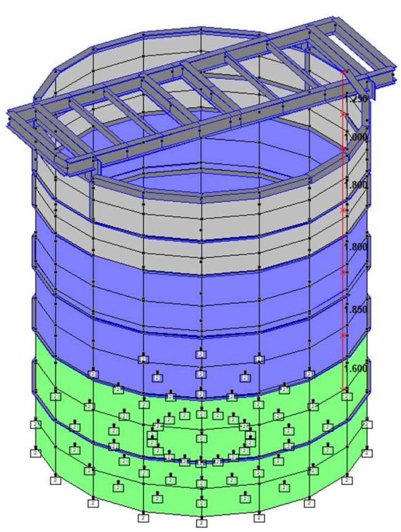
Code and reference that used for this calculation listed below :

- API STD 650 2018 – Welded Tanks for Oil Storage
- SNI 1729:2020 – Spesifikasi untuk Bangunan Gedung Baja Struktural

4. Design

4.1 Isometric Model

Analysis design for the tank use STAAD Pro software. Tank model picture showed below :



Material			
PLATE			
Shell elev.(m)	Main Thickness (mm)	Corrosion Allowance (mm)	Design Thickness (mm)
0 - 3.6	9	3	12
3.6 - 7.2	7	3	10
7.2 - 9.3	5	3	8
STIFFENER			
Profile elev. (m)	Type		
1.6	L.130.130.12		
3.45	L.130.130.12		
5.25	L.130.130.12		
7.05	L.130.130.12		
8.05	L.130.130.12		
9.3	L.200.200.25		
PLATFORM SUPPORT			
Profile elev. (m)	Type		
9.3	Half.Tee.300.300.10.15		

Picture 1. Tank Model and Properties

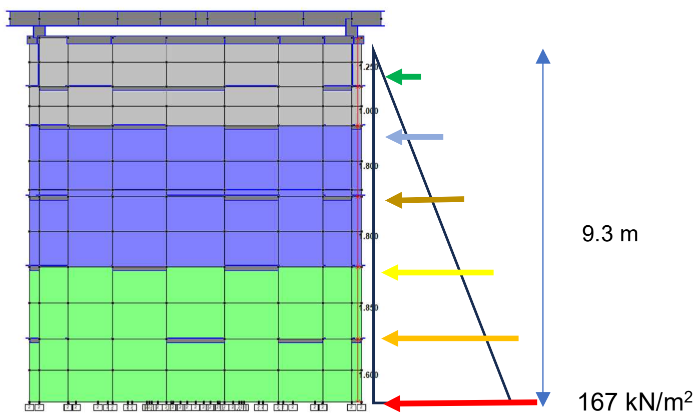
4.2 Load and Combination

4.2.1 Daad Load

Unit weight of steel used as calculation is 78.5 kN/m3.

4.2.2 Hidrostatic Load

Hidrostatic load is pressure load from fluida content. Specific gravity fluida is 1.82 Ton/m^3



Hidrostatic load : 1.82 x 9.3 = 16.93 Ton/m^2 → 166.04 kN/m^2

4.2.3 Agitator and Platform Load

- Point load to represent platform load taken from document : *3655.15 - Joint Reactions Platform on Top of CIL Tanks (4 support)*

AGITATOR LOAD

Mixer Mass	23.77	kN
Bend. Moment	29.091	kNm
Torque	34.529	kNm
Axial Load	34.975	kN

Point Load 2

TANK LOADS	
LOADS: FACTORED	
MIXER MASS (kg)	2377
BEND. MOMENT(Nm)	29091
TORQUE (Nm)	34529
AXIAL LOAD (N)	34975

Load on model as follows :

Mixer Mass	17.83	kN
Bend. Moment	21.82	kNm
Torque	25.90	kNm
Axial Load	26.23	kN

GRATING

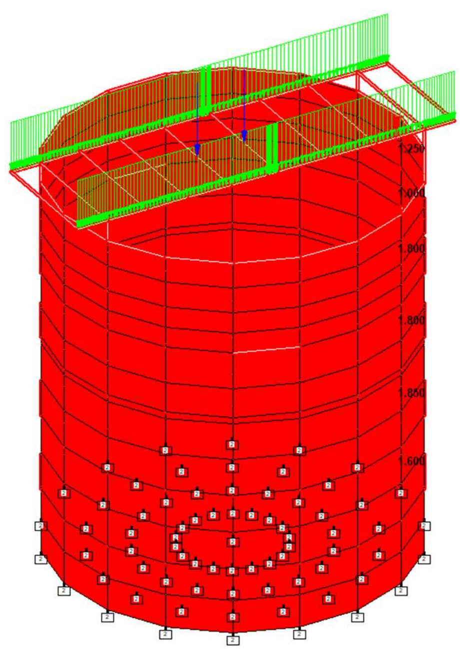
Length	=	9.8	m
Wide	=	3	m
q area	=	0.45	kPa
Input Load			
q line	=	**0.675**	kN/m

Live Load On Agitator Platform

Length	=	9.8	m
Wide	=	3	m
q area	=	5	kPa

Load on Model :

q line	=	**7.5**	kN/m



Picture 2. Agitator Input Load

4.2.4 Seismic Load

Seismic load calculated based on API 650.

- The seismic overturning moment at the base of the tank shell shall be the SRSS summation of the impulsive and convective components multiplied by the respective moment arms to the center of action of the forces unless otherwise specified.

Ringwall Moment, M_{rw}:

$$M_{rw} = \sqrt{[A_i(W_iX_i + W_sX_s + W_rX_r)]^2 + [A_c(W_cX_c)]^2} \quad \text{(E.6.1.5-1)}$$

Equation Ai :

Impulsive spectral acceleration parameter, A_i:

$$A_i = S_{DS}\left(\frac{I}{R_{wi}}\right) = 2.5QF_aS_0\left(\frac{I}{R_{wi}}\right) \quad \text{(E.4.6.1-1)}$$

However, $A_i \geq 0.007$ (E.4.6.1-2)

and, for $S_1 \geq 0.6$:

$$A_i \geq 0.5S_1\left(\frac{I}{R_{wi}}\right) = 0.625S_P\left(\frac{I}{R_{wi}}\right) \quad \text{(E.4.6.1-3)}$$

I = 1 *(category II)*

Sds = 0.806

Rwi 3.5

Table E.4—Response Modification Factors for ASD Methods

Anchorage system	R_{wi}, (impulsive)	R_{wc}, (convective)
Self-anchored	3.5	2
Mechanically-anchored	4	2

Ai = 0.23

Equation Ac

Convective spectral acceleration parameter, A_c:

When, $T_C \leq T_L$ $$A_c = KS_{D1}\left(\frac{1}{T_c}\right)\left(\frac{I}{R_{wc}}\right) = 2.5KQF_aS_0\left(\frac{T_s}{T_c}\right)\left(\frac{I}{R_{wc}}\right) \leq A_i \quad \text{(E.4.6.1-4)}$$

When, $T_C > T_L$ $$A_c = KS_{D1}\left(\frac{T_L}{T_c^2}\right)\left(\frac{I}{R_{wc}}\right) = 2.5KQF_aS_0\left(\frac{T_sT_L}{T_c^2}\right)\left(\frac{I}{R_{wc}}\right) \leq A_i \quad \text{(E.4.6.1-5)}$$

Ks	=	0.58
Tc	=	3.03
Rwc	=	2
K	=	1.5
S_{D1}	=	0.582
Ac	=	0.14

Equation Wi and Xi :

E.6.1.1 Effective Weight of Product

The effective weights W_i and W_c shall be determined by multiplying the total product weight, W_p, by the ratios W_i/W_p and W_c/W_p, respectively, Equations E.6.1.1-1 through E.6.1.1-3.

When D/H is greater than or equal to 1.333, the effective impulsive weight is defined in Equation E.6.1.1-1:

$$W_i = \frac{\tanh\left(0.866\frac{D}{H}\right)}{0.866\frac{D}{H}} W_p \qquad \text{(E.6.1.1-1)}$$

When D/H is less than 1.333, the effective impulsive weight is defined in Equation E.6.1.1-2:

$$W_i = \left[1.0 - 0.218\frac{D}{H}\right] W_p \qquad \text{(E.6.1.1-2)}$$

When D/H is greater than or equal to 1.3333, the height X_i is determined by Equation E.6.1.2.1-1:

$$X_i = 0.375H \qquad \text{(E.6.1.2.1-1)}$$

When D/H is less than 1.3333, the height X_i is determined by Equation E.6.1.2.1-2:

$$X_i = \left[0.5 - 0.094\frac{D}{H}\right] H \qquad \text{(E.6.1.2.1-2)}$$

D	=	8.5	m
H	=	9.3	m
D/H	=	0.91	
ɣ	=	1.82	
Wp	=	9425.97	kN
perimeter	=	26.71	m
3.67H/D	=	4.02	
Wi	**=**	**7547.87**	**kN**
Xi	**=**	**3.85**	**m**

Equation Wc and Xc :

The effective convective weight is defined in Equation E.6.1.1-3:

$$W_c = 0.230\frac{D}{H}\tanh\left(\frac{3.67H}{D}\right)W_p \quad \text{(E.6.1.1-3)}$$

The height X_c is determined by Equation E.6.1.2.1-3:

$$X_c = \left[1.0 - \frac{\cosh\left(\frac{3.67H}{D}\right) - 1}{\frac{3.67H}{D}\sinh\left(\frac{3.67H}{D}\right)}\right]H \quad \text{(E.6.1.2.1-3)}$$

Wc	**=**	**1545.28 kN**
Xc	**=**	**7.45 m**

Value of Ws and Xs :

Ws = Total weight of tank shell and appurtenances

Xs = Height from bottom of the tank shell to the shell's center of gravity

L.130.130.12

A	=	2976 mm^2	=	0.002976 m^2
w	=		=	6.24 kN
n			=	5
Weight Total L.130			=	31.20 kN

L.200.200.25

A	=	9375 mm^2	=	0.009375 m^2
w			=	19.66 kN
n			=	1
Weight Total L.130			=	19.66 kN

H.300.300.15.10 H.Tee

A	=	11850 mm^2	=	0.01185 m^2
w			=	1.16 kN
n			=	4
Weight Total H.300 tee			=	4.65 kN

Shell T 12 mm

A	=	0.32 m^2
w	=	90.59 kN

Shell T 10 mm

A	=	0.27 m^2
w	=	75.49 kN

Shell T 8 mm

A	=	0.21 m^2
w	=	37.75 kN

TOTAL WEIGHT (Ws)		**259.35 kN**
H tank	**=**	**9.30 m**
Xs	**=**	**4.65 m**

From calculation above,

(Ai . Wi) / perimeter	=	65.07 kN/m, at H =	3.85 m
(Ai . Ws) / perimeter	=	2.24 kN/m, at H =	4.65 m
(Ac . Wc) / perimeter	=	10.66 kN/m, at H =	7.07 m

Simplification

W	=	77.96 kN/m
H	=	4.31 m

4.2.5 Wind Load

Wind load calculated based on SNI 1727 : 2020.

4.2.6 Load Combination

Load combination based on SNI 1729 : 2020

Service load combination :

1. D
2. $D + L$
3. $D + (L_r \text{ atau } R)$
4. $D + 0{,}75\,L + 0{,}75(L_r \text{ atau } R)$
5. $D + 0{,}6\,W$
6. $D + 0{,}75\,(0{,}6\,W) + 0{,}75\,L + 0{,}75\,(L_r \text{ atau } R)$
7. $0{,}6D + 0{,}6\,W$

8. $1{,}0D + 0{,}7E_v + 0{,}7E_h$
9. $1{,}0D + 0{,}525E_v + 0{,}525E_h + 0{,}75L$
10. $0{,}6D - 0{,}7E_v + 0{,}7E_h$

Ultimate load combination :

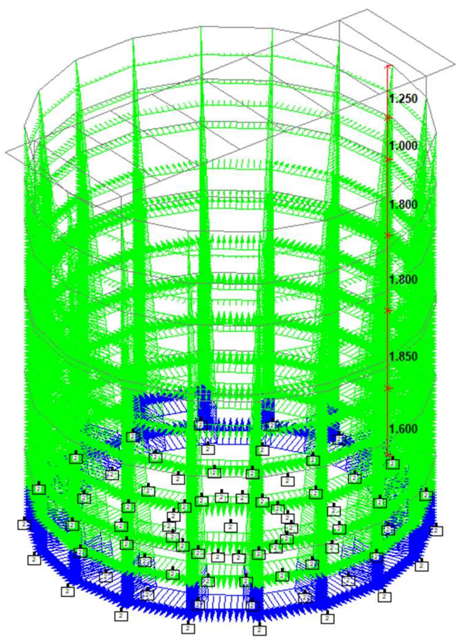
1. $1{,}4D$
2. $1{,}2\,D + 1{,}6\,L + 0{,}5\,(L_r \text{ atau } R)$
3. $1{,}2D + 1{,}6\,(L_r \text{ atau } R) + (L \text{ atau } 0{,}5\,W)$
4. $1{,}2D + 1{,}0\,W + L + 0{,}5(L_r \text{ atau } R)$
5. $0{,}9\,D + 1{,}0\,W$

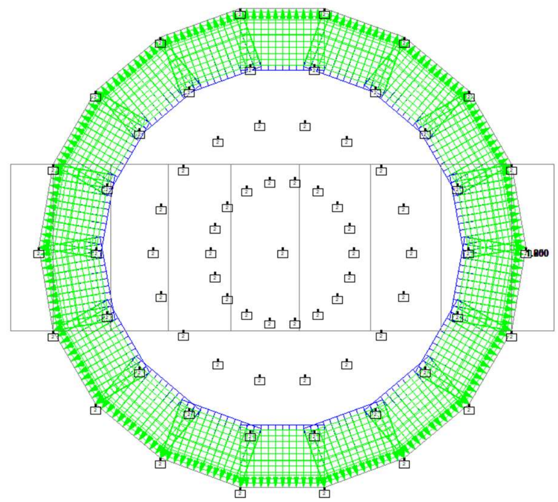
6. $1{,}2D + E_v + E_h + L$
7. $0{,}9D - E_v + E_h$

4.3 Analysis Design

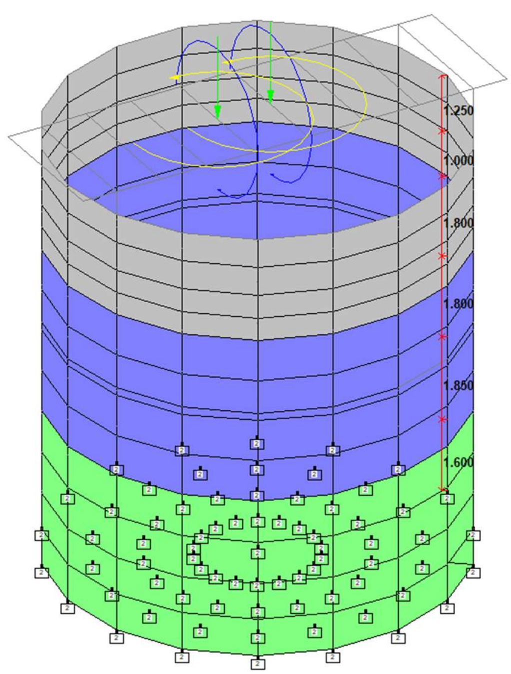
4.3.1 Input Model

a. Hidrostatic Load (MAX =167 kN/m2)

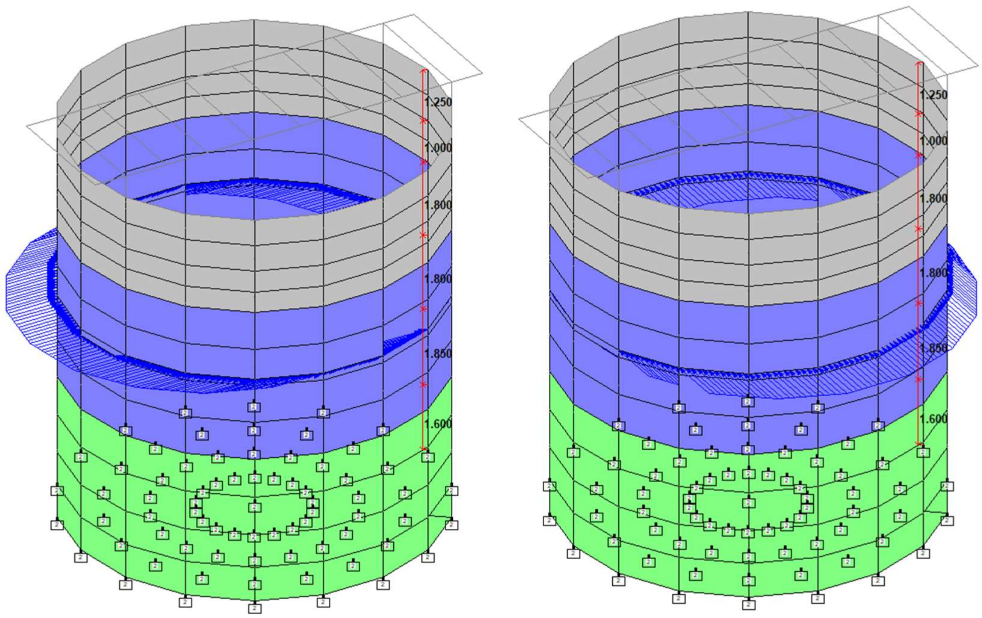




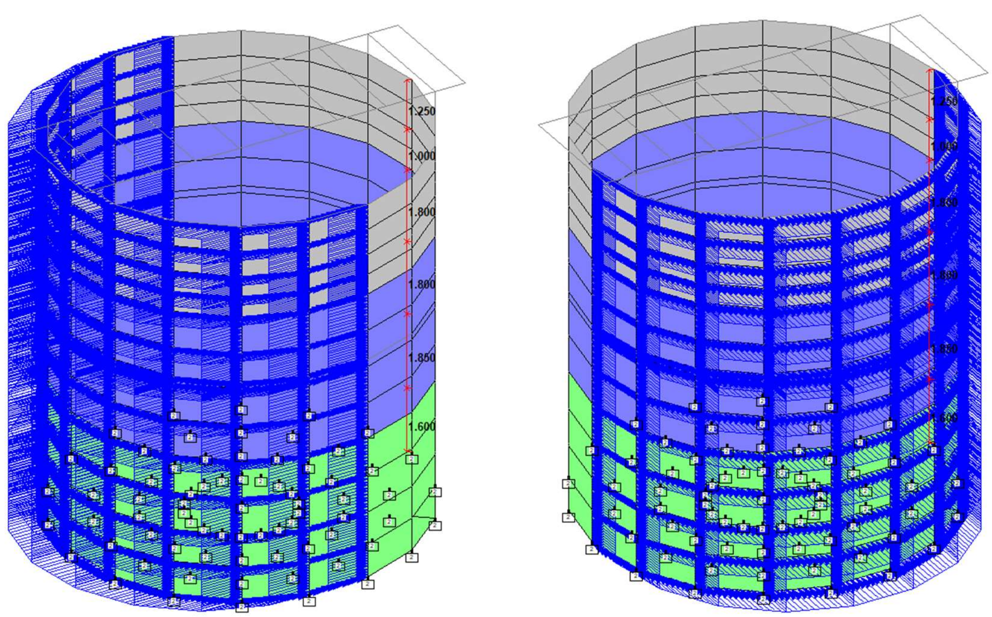
b. Agitator Load



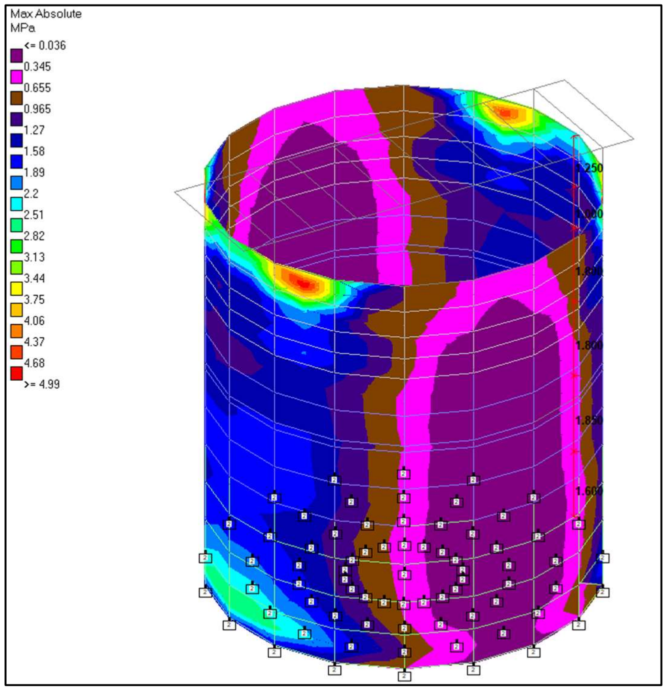
c. Seismic Load (Wi = 77.96 kN/m)



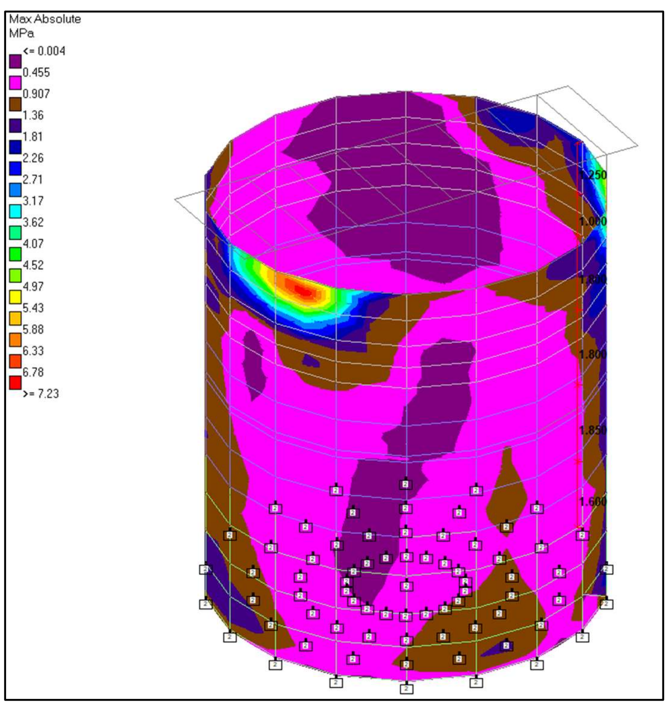
d. Wind Load (0.9 kN/m2)



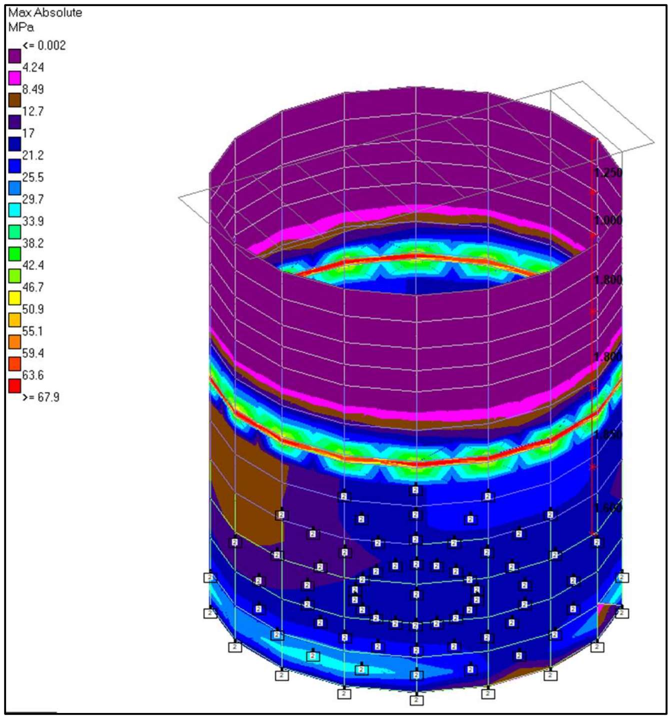
4.3.2 Output Data



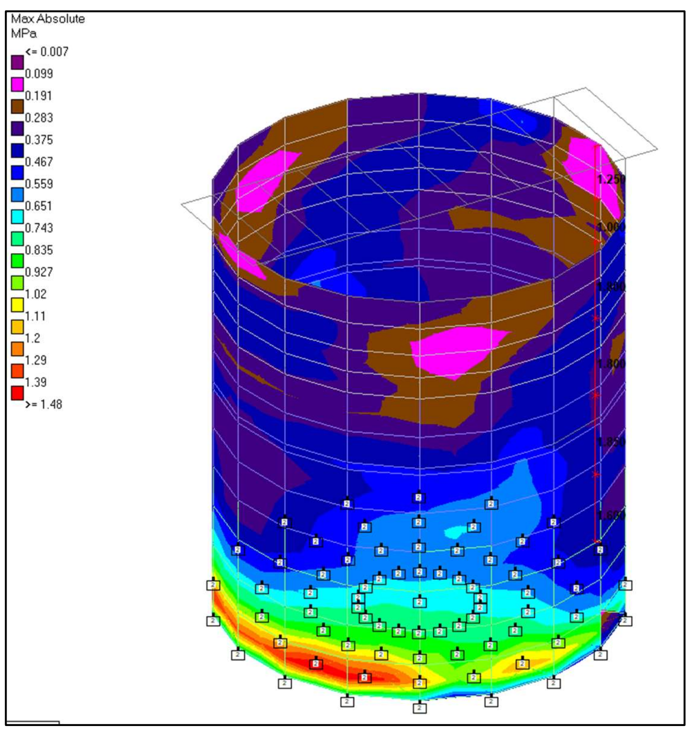
Stress Shell due Selfweight (max : 5 MPa)



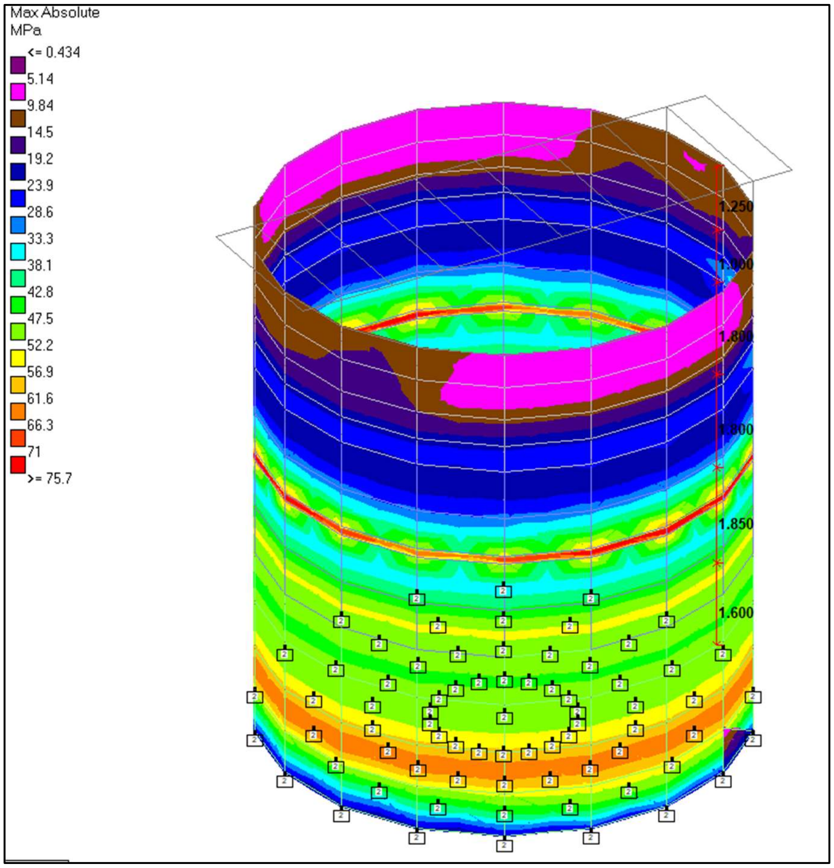
Stress Shell due Platform Support (max : 7.3 MPa)



Stress Shell due Seismic Load EQx (max : 67.9 MPa)



Stress due Windload Wx+ (max : 1.48 MPa)

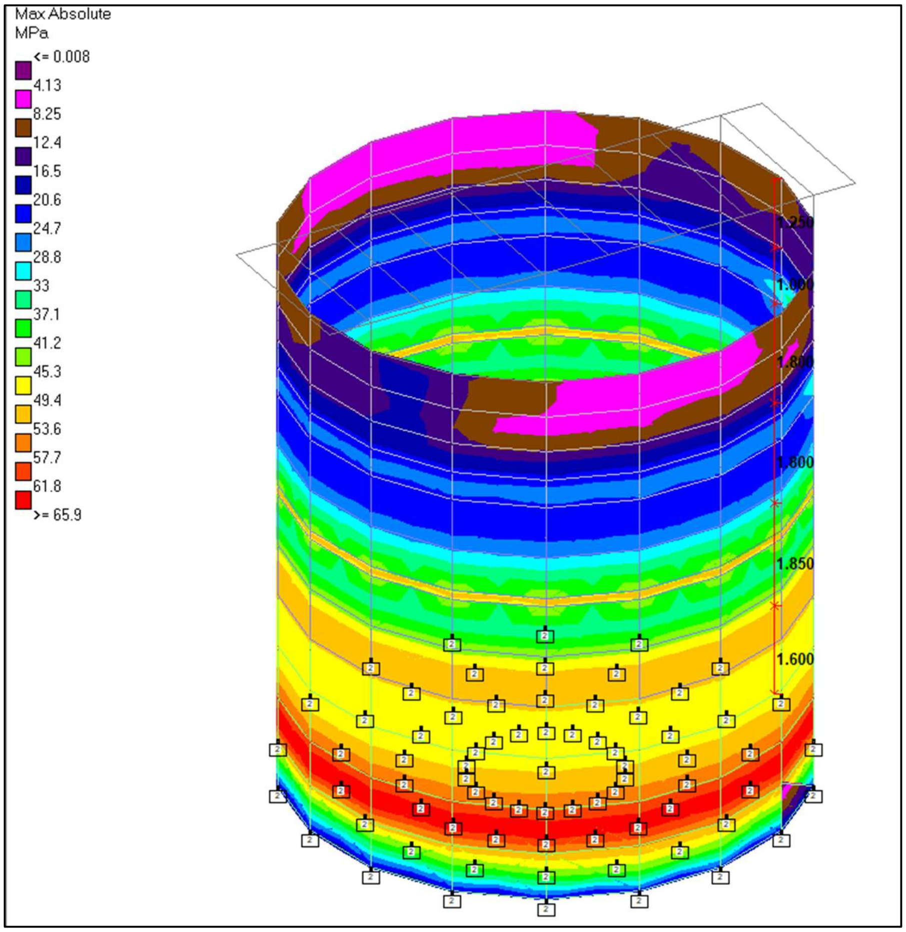


Stress due Load Combination (Service) (max : 76 MPa)

Stress Summary Table

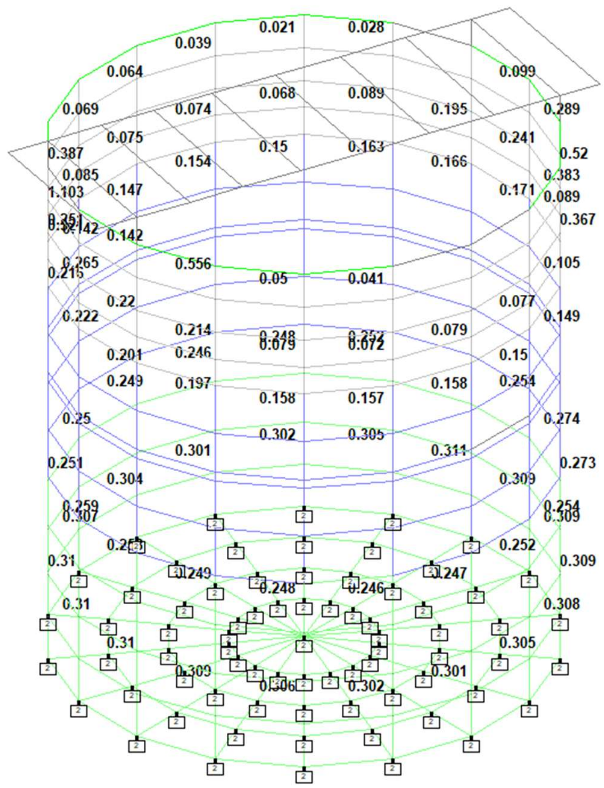
	Plate	L/C	Shear (Local)		Membrane (Local)			Bending Moment (Local)		
			SQX MPa	SQY MPa	SX MPa	SY MPa	SXY MPa	MX kN-m/m	MY kN-m/m	MXY kN-m/m
Max Qx	326	19 201	1.537	-0.073	-1.196	0.275	-13.598	0.002	0.004	-0.294
Min Qx	335	19 201	-1.536	0.077	1.123	0.086	13.657	-0.002	-0.004	0.294
Max Qy	337	22 204	-0.042	2.659	41.845	-2.576	-0.137	-0.059	-0.146	0.008
Min Qy	337	20 202	0.044	-2.664	-41.881	2.522	-0.904	0.06	0.146	-0.008
Max Sx	88	18 103	0	-0.028	65.44	-5.52	-0.286	-0.006	-0.021	0
Min Sx	328	22 204	0.041	-2.657	-41.929	2.487	-0.924	0.06	0.144	-0.008
Max Sy	57	22 204	0	-0.034	17.637	14.798	3.768	-0.023	-0.075	-0.001
Min Sy	61	19 201	0	0.044	-21.516	-18.112	1.766	0.028	0.092	0
Max Sxy	728	20 202	-0.001	-0.003	0.025	-1.977	16.751	0.002	0.004	0.002
Min Sxy	712	21 203	0.001	0	0.013	0.314	-16.346	0	-0.001	-0.002
Max Mx	337	20 202	0.044	-2.664	-41.881	2.522	-0.904	0.06	0.146	-0.008
Min Mx	340	25 207	-0.162	2.171	64.015	-5.589	1.178	-0.088	-0.253	0.032
Max My	340	19 201	0.23	-2.632	-41.75	0.074	-2.185	0.059	0.146	-0.043
Min My	337	26 208	-0.032	2.184	64.835	-1.724	-0.368	-0.088	-0.257	0.006
Max Mxy	326	21 203	-1.535	0.073	1.137	0.138	13.74	-0.002	-0.004	0.294
Min Mxy	335	21 203	1.536	-0.073	-1.205	0.235	-13.685	0.001	0.003	-0.294

Maximum stress Sx occurred due combination load 103 : 1.0DL + 1.0 EQ + 1LL + Hidrostatic



Stress due Combination 103 (max : 66 MPa)

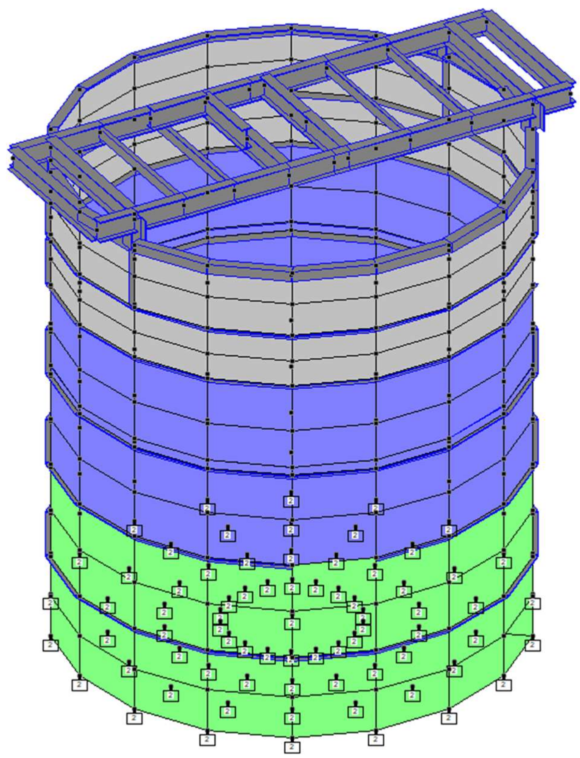
All Stress ratio stiffener frame condition are under allowance (1) :



5. Conclusion

- All component, steel frame and steel shell with current configuration is capable to resist the loads.

- The configuration as follows :



Material			
PLATE			
Shell elev.(m)	Main Thickness (mm)	Corrosion Allowance (mm)	Design Thickness (mm)
0 - 3.6	9	3	12
3.6 - 7.2	7	3	10
7.2 - 9.3	5	3	8
STIFFENER			
Profile elev. (m)	Type		
1.6	L.130.130.12		
3.45	L.130.130.12		
5.25	L.130.130.12		
7.05	L.130.130.12		
8.05	L.130.130.12		
9.3	L.200.200.25		
PLATFORM SUPPORT			
Profile elev. (m)	Type		
9.3	Half.Tee.300.300.10.15		

Anchor Bolt Design

A-s = Installed Bolt Nominal Root Area (mm^2)
A-s-r = Anchor Required Root Area (mm^2)
Av = Seismic Vertical Earthquake Acceleration Coefficient (g)
Ca-anchor = Anchor Corrosion Allowance (mm)
D = Tank nominal diameter (m)
Dac = Bolt Circle Diameter (m)
Fp = Design Pressure Operating Ratio
Fty = Minimum Yield Strength of the Bottom Shell Course (MPa)
Fy = Anchor Yield Strength per API-650 Table 5.21a (MPa)
Fy-ambient = Anchor Yield Strength at Ambient Temperature per API-650 Table 5.21a (MPa)
H = Tank Height (m)
MWS = Shell Wind Overturning Moment (N.m)
Ma-anchor = Anchor Material
Mrw = Seismic Overturning Moment (N.m)
N = Anchors Quantity
N-min = Minimum Required Number of Anchors per API-650 5.12.3
OD = Tank Outer diameter (m)
P = Internal Pressure (kPa)
P-attachment = Anchor Attachment Design Load per API-650 5.12.13 and Steel Plate Engineering Data-Volume 2 Part V (N)
PWR = Roof Wind Pressure (kPa)
Pt = Test Pressure (kPa)
Sd = Allowable Anchor Stress per API-650 Table 5.21a (MPa)
Sd-shell = Allowable Shell Stress at Anchor Attachment per API-650 Table 5.21a (MPa)
Tb = Load per Anchor per API-650 5.12.2 (N)
U = Net Uplift Load per API-650 5.12.2 (N)
W1 = Corroded Weight of the Roof Plates Plus the Corroded Weight of the Shell and any Other Corroded Permanent Attachments Acting on the Shell (N)
W2 = Corroded Weight of the Shell and any Corroded Permanent Attachments Acting on the Shell Including the Portion of the Roof Plates and Framing Acting on The Shell (N)
W3 = Nominal Weight of the Roof Plates Plus the Nominal Weight of the Shell and any Other Permanent Attachments Acting on the Shell (N)
Wr-pl = Roof Plates Nominal Weight (N)
Wr-pl-corr = Roof Corroded Plates Weight (N)
Wrs-pl-corr = Roof Plates Corroded Weight Acting on The Shell (N)
Ws-framing = Shell New Framing Weight (stiffeners) (N)
Ws-framing-corr = Shell Corroded Framing Weight (stiffeners) (N)
Ws-pl = Shell Plates Nominal Weight (N)
Ws-pl-corr = Shell Corroded Plates Weight (N)
Wss = Roof Structure Nominal Weight Acting on The Shell (N)
Wss-corr = Roof Structure Corroded Weight Acting on The Shell (N)
Y-bolt = Anchor Yield Load (N)
d = Anchor Bolt Diameter (mm)
d-req = Bolt Required Diameter per ANSI B1.1 (mm)
p = Bolt Thread Pitch (mm)
position_angles = Anchors Position Angles (deg)

Av = 0.38 g
Ca-anchor = 1.5 mm
D = 8.5 m
Dac = 8.69 m
Fp = 0.4
Fty = 250.0 MPa
H = 9.3 m
MWS = 114,650.6 N.m
Ma-anchor = A307-B
Mrw = 8,259,828.0 N.m
N = 16
OD = 8.52 m
P = 0.0 kPa
PWR = 0 kPa
Pt = 0.0 kPa
Wr-pl = 0.0 N
Wr-pl-corr = 0.0 N
Wrs-pl-corr = 0 N
Ws-framing = 15,192.95 N
Ws-framing-corr = 12,032.89 N
Ws-pl = 198,031.56 N
Ws-pl-corr = 140,680.87 N
Wss = 78,712.88 N
Wss-corr = 0.0 N
d = 48 mm
p = 5.0 mm
position_angles = [0 22.5 45 67.5 90 112.5 135 157.5 180 202.5 225 247.5 270 292.5 315 337.5] deg

Anchors Spacing Requirements
Max Allowable Spacing Between Anchors at Shell Outer Diameter per API-650 5.12.3
Max Allowable Spacing (max_allowable_spacing) = 3 m
Actual Spacing (actual_spacing) = 1.67 m

actual_spacing <= max_allowable_spacing ==> PASS

N-min = CEILING(((pi * OD) / 3))
N-min = CEILING(((pi * 8.524) / 3))
N-min = 9

N >= N-min ==> PASS

Anchors meet spacing requirements.

Anchors Average Spacing (half the span on each side of the anchor) at Bolt Circle
Anchors are equally spaced.
Average Spacing (average_spacing) = 1.71 m
Bolt loads will be based on equally spaced anchors.

Anchor Material Properties
Material (A307-B) = A307-B
Minimum Tensile Strength (Sut-anchor) = 415 MPa
Minimum Yield Strength (Sy-anchor) = 250 MPa
Minimum Yield Strength at Ambient Temperature (Sy-ambient-anchor) = 250 MPa

Fy = MIN(Sy-ambient-anchor , 380)
Fy = MIN(250 , 380)
Fy = 250 MPa

Fy-ambient = MIN(Sy-ambient-anchor , 380)
Fy-ambient = MIN(250 , 380)
Fy-ambient = 250 MPa

Uplift Load Cases per API-650 Table 5.21a
W1 = Ws-pl-corr + Ws-framing-corr + Wr-pl-corr
W1 = 140,680.867 + 12,032.8854 + 0.0
W1 = 152,713.75 N

W2 = Ws-pl-corr + Ws-framing-corr + Wrs-pl-corr + Wss-corr
W2 = 140,680.867 + 12,032.8854 + 0 + 0.0
W2 = 152,713.75 NW3 = Ws-pl + Ws-framing + Wr-pl + Wss

W3 = Ws-pl + Ws-framing + Wr-pl + Wss
W3 = 198,031.5614 + 15,192.9471 + 0.0 + 78,712.8847
W3 = 291,937.39 N

Uplift Case 1: Design Pressure Only
U = (P * (D^2) * 785) - W1
U = (0.0 * (8.5^2) * 785) - 152,713.7525
U = -152,713.75 (Set to 0 N since it cannot be less than 0)

Tb = U / N
Tb = 0 / 16
Tb = 0 N

Sd = (5 / 12) * Fy
Sd = (5 / 12) * 250
Sd = 104.17 MPa

A-s-r = Tb / Sd
A-s-r = 0 / 104.1667
A-s-r = 0.0 mm^2

P-attachment = 1.5 * Tb
P-attachment = 1.5 * 0
P-attachment = 0.0 N

Sd-shell = (2 / 3) * Fty
Sd-shell = (2 / 3) * 250.0
Sd-shell = 166.67 MPa

Uplift Case 2: Test Pressure Only
U = (Pt * (D^2) * 785) - W3
U = (0.0 * (8.5^2) * 785) - 291,937.3931
U = -291,937.39 (Set to 0 N since it cannot be less than 0)

Tb = U / N
Tb = 0 / 16
Tb = 0 N

Sd = (5 / 9) * Fy-ambient
Sd = (5 / 9) * 250
Sd = 138.89 MPa

A-s-r = Tb / Sd
A-s-r = 0 / 138.8889
A-s-r = 0.0 mm^2

P-attachment = 1.5 * Tb
P-attachment = 1.5 * 0
P-attachment = 0.0 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

Uplift Case 3: Wind Load Only
U = ((PWR * (D^2) * 785) + ((4 * MWS) / D)) - W2
U = ((0 * (8.5^2) * 785) + ((4 * 114,650.6013) / 8.5)) - 152,713.7525
U = -98,760.53 (Set to 0 N since it cannot be less than 0)

Tb = U / N
Tb = 0 / 16
Tb = 0 N

Sd = 0.8 * Fy
Sd = 0.8 * 250
Sd = 200.0 MPa

A-s-r = Tb / Sd
A-s-r = 0 / 200.0
A-s-r = 0.0 mm^2

P-attachment = 1.5 * Tb
P-attachment = 1.5 * 0
P-attachment = 0.0 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

Uplift Case 4: Seismic Load Only
U = ((4 * Mrw) / D) - (W2 * (1 - (0.4 * Av)))
U = ((4 * 8,259,828.0044) / 8.5) - (152,713.7525 * (1 - (0.4 * 0.3808)))
U = 3,757,525.49 N

Tb = U / N
Tb = 3,757,525.4907 / 16
Tb = 234,845.34 N

Sd = 0.8 * Fy
Sd = 0.8 * 250
Sd = 200.0 MPa

A-s-r = Tb / Sd
A-s-r = 234,845.3432 / 200.0
A-s-r = 1,174.23 mm^2

P-attachment = 3 * Tb
P-attachment = 3 * 234,845.3432
P-attachment = 704,536.03 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

Uplift Case 5: Design Pressure + Wind Load
U = ((((Fp * P) + PWR) * (D^2) * 785) + ((4 * MWS) / D)) - W1
U = ((((0.4 * 0.0) + 0) * (8.5^2) * 785) + ((4 * 114,650.6013) / 8.5)) - 152,713.7525
U = -98,760.53 (Set to 0 N since it cannot be less than 0)

Tb = U / N
Tb = 0 / 16
Tb = 0 N

Sd = (5 / 9) * Fy
Sd = (5 / 9) * 250
Sd = 138.89 MPa

A-s-r = Tb / Sd
A-s-r = 0 / 138.8889
A-s-r = 0.0 mm^2

P-attachment = 1.5 * Tb
P-attachment = 1.5 * 0
P-attachment = 0.0 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

Uplift Case 6: Design Pressure + Seismic Load
U = ((Fp * P * (D^2) * 785) + ((4 * Mrw) / D)) - (W1 * (1 - (0.4 * Av)))
U = ((0.4 * 0.0 * (8.5^2) * 785) + ((4 * 8,259,828.0044) / 8.5)) - (152,713.7525 * (1 - (0.4 * 0.3808)))
U = 3,757,525.49 N

Tb = U / N
Tb = 3,757,525.4907 / 16
Tb = 234,845.34 N

Sd = 0.8 * Fy
Sd = 0.8 * 250
Sd = 200.0 MPa

A-s-r = Tb / Sd
A-s-r = 234,845.3432 / 200.0
A-s-r = 1,174.23 mm^2

P-attachment = 3 * Tb
P-attachment = 3 * 234,845.3432
P-attachment = 704,536.03 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

Uplift Case 7: Frangibility Pressure
Not applicable. It is applied if the roof to shell joint is frangible.

Summary of Uplift Cases

Uplift Cases	Total Uplift Load (N)	Load per Anchor (N)	Anchor Allowable Stress (MPa)	Anchor Required Area (mm^2)	Anchor Bolt Required Diameter (mm)	Attachment Design Load (N)	Allowable Shell Stress at Anchor Attachment (MPa)
Design Pressure	0	0	104.17	0.0	9.13	0.0	166.67
Test Pressure	0	0	138.89	0.0	9.13	0.0	208.33
Wind Load	0	0	200.0	0.0	9.13	0.0	208.33
Seismic Load	3,757,525.49	234,845.34	200.0	1,174.23	47.8	704,536.03	208.33
Design Pressure + Wind	0	0	138.89	0.0	9.13	0.0	208.33
Design Pressure + Seismic	3,757,525.49	234,845.34	200.0	1,174.23	47.8	704,536.03	208.33

- Anchor Bolt Required Diameter = SQRT((A-s-r * (4 / pi))) + (1.22687 * p) + (Ca-anchor * 2)
- Governing Uplift Case = Seismic Load
- Anchor Bolt Minimum Required Area = 1,174.23 mm^2

Bolt Required Diameter per ANSI B1.1

d-req = SQRT((A * (4 / pi))) + (1.22687 * n) + (Ca * 2)
d-req = SQRT((1,174.2267 * (4 / pi))) + (1.22687 * 5.0) + (1.5 * 2)
d-req = 47.8 mm

d >= d-req ==> PASS

A-s = (pi / 4) * ((d - (1.22687 * n))^2)
A-s = (pi / 4) * ((48 - (1.22687 * 5.0))^2)
A-s = 1,376.59 mm^2

Y-bolt = A-s * Sy-ambient-anchor
Y-bolt = 1,376.593 * 250
Y-bolt = 344,148.25 N

Anchorage Summary

Required Number of Anchors = 9
Actual Number of Anchors = 16
Bolt Hole Circle Radius = 4.35 m
Required Bolt Diameter = 47.8 mm
Actual Bolt Diameter = 48 mm
Bolt Thread Pitch = 5.0 mm