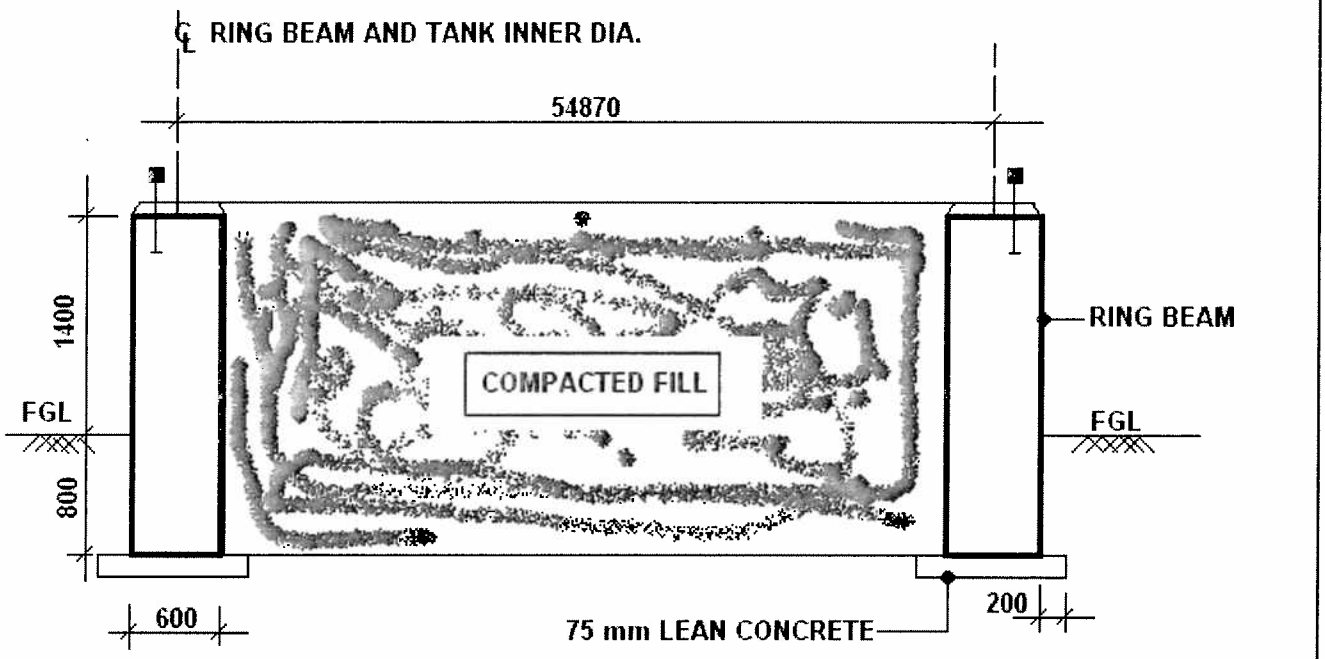
TANK FOUNDATION RING WALL DESIGN
CSA - A23.3-94
(CANADIAN CODE)

1.0 ENGINEERING AND DESIGN SKETCHES:



TYPICAL CROSS SECTIONAL VIEW OF RING WALL FOUNDATION

2.0 DESIGN PARAMETERS (PER CANADIAN CODE CSA A23.3-94)

Concrete Parameters

Specified compressive strength of Concrete, $f_c = 30$ MPa

Unit weight of concrete, $\gamma_{conc} = 24.0 \frac{kN}{m^3}$

Elastic modulus of concrete: $E_c = 4500 \sqrt{\frac{f_c}{MPa}}$ MPa $\quad E_c = 2.46 \times 10^4$ MPa

Factor for concrete, $\phi_c = 0.60$ Factor for reinforcing bar, $\phi_s = 0.85$

Factor to account for low density concrete, $\lambda = 1.0$

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Reinforcing Steel Parameters

Specified Yield strength of Reinforcement, $f_y = 400$ MPa Elastic modulus of re-bar: $E_{rebar} = 200000$ MPa

Concrete Re-bar cover for pile, cover = 75 mm

Anchor Bolt Parameters,

Tensile strength of Anchor Bolt (A307), $F_{su\_AB} = 414$ MPa Resistance fators for Anchor rods, $\phi_{ar} = 0.67$

Soil Parameters,

Density of soil $\gamma_{soil} = 21.0 \frac{kN}{m^3}$ Soil Height under the Tank, $H_{soil} = 2.2$ m Density of water $\gamma_w = 9.8 \frac{kN}{m^3}$

Allowable net Bearing Capacity, $SBC_{net\_all} = 200$ kPa Earth pressure coefficient at rest, $k_o = 0.45$

3.0 RING BEAM DESIGN:

3.1 TANK DATA (By Vendor):

Inner dia. of Tank, ID = 54870 mm Height of Tank, $H_{tank} = 17000$ mm

Load on Tank shell:

As built Metal load, $Metal = 41781 \frac{N}{m}$ Corroded metal Load, $Metal_{cor} = 33800 \frac{N}{m}$

Roof Live Load, $LL_{roof} = 5827 \frac{N}{m}$ Snow Load, $SL = 7576 \frac{N}{m}$

Shell insulation, $Shell_{ins} = 1468 \frac{N}{m}$ Roof insulation, $Roof_{ins} = 485 \frac{N}{m}$

Design Pressure, $Pr_{design} = -27453 \frac{N}{m}$ External Design Pressure, $Vacuum = 3432 \frac{N}{m}$

Wind Load, $Wind_{shell} = 12845 \frac{N}{m}$ Wind Shear, $Shear = 461$ kN

Anchor Bolt dia. $d_{bolt} = 1.25$ in Bolt circle dia, $BCD = 55150$ mm Total no of bolts, $n_{bolt} = 57$

Total Wind Moment on ring wall foundation, $W_{mom} = 3936$ kN m

Maximum design Tension load on each Bolt, $T_{bolt} = 19.7$ kN (Design tension)

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Load on tank Bottom Plate:

Product Static Pressure: Pr_{st} = 150 kPa Bottom Plate Static Pressure, Pr_{plt} = 0.7 kPa

Internal Design Pressure Pr_d = 2.0 kPa

3.2 Detail of Ring Beam (Refer sketch above):

Assumption: Tank inner dia is considered as the centerline dimension of foundation ring beam.

Depth of Ring Beam Depth = 2200 mm Width of Ring Beam, Width = 600 mm

Inner dia of Ring Beam, $Ring_{ID}$ = ID − Width $Ring_{ID}$ = 54270 mm

Outer dia of Ring Beam, $Ring_{OD}$ = ID + Width $Ring_{OD}$ = 55470 mm

3.3 Load Cases and Load Combinations:

Following load cases and load combinations are considered for ring beam design.

Load cases: 1.0 Self Weight of the Tank (SW)
2.0 Wind Load (WL)
3.0 Product Weight (PW)
4.0 Operating Design Pressure in the tank (DP)
5.0 Vacuum Pressurein the Tank (empty condition) (VP)

Load Combinations for Soil Bearing Pressure Check: LC1: SW+PW
LC2: SW+PW+DP+SL
LC3: SW (corroded)+WL
LC4: SW (corroded)+WL+VP

Load Combinations for Ring Beam design: ULC1: 1.5*SW+1.5*PW+1.5*DP

3.4 Ring Beam Sizing Check and Soil Bearing pressure check:

- Design of ring wall shall ensure that the average soil stress under the ring wall shall be equivalent to the average unit soil stress under the confined earth at the same depth.
- The thickness of ringwall shall be determined based on the soil bearing capacity. To reduce differential settlement, the long term bearing pressure beneath the wall and the tank shall be equal.
- Reinforced concrete ringwalls shall be designed in accordance CSA A23.3-94. The minimum thickness of reinforced concrete ringwalls shall be 500 mm.

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Soil net Bearing Pressure at 2.2m depth, $SBC_{net\_all} = 200\ kPa$

Soil Gross Bearing pressure at 2.2m depth, $SBC_{gross\_all} = SBC_{net\_all} + \gamma_{soil}\ 0.5\ m$ $SBC_{gross\_all} = 210.5\ kPa$

LOAD COMBINATION # LC1: SW+PW

Load under Ring Beam, $SBC_{ring\_1} = \frac{Metal + Shell_{ins} + Roof_{ins}}{Width} + \frac{Pr_{st}}{2} + \gamma_{conc}\ Depth$ $SBC_{ring\_1} = 200.69\ kPa$

Bearing Pressure Check, $SBC_{check\_1} = if(SBC_{ring\_1} \le SBC_{gross\_all}, "OK", "CHECK")$ $SBC_{check\_1} = "OK"$

Soil Bearing pressure under the tank, $SBC_{tank\_1} = Pr_{plt} + Pr_{st} + H_{soil}\ \gamma_{soil}$ $SBC_{tank\_1} = 196.9\ kPa$

Bearing Pressure Check, $SBC_{check\_2} = if(SBC_{tank\_1} \le SBC_{gross\_all}, "OK", "CHECK")$ $SBC_{check\_2} = "OK"$

LOAD COMBINATION # LC2 SW+PW+DP+SL

Load under Ring Beam, $SBC_{ring\_2} = \frac{Metal + Shell_{ins} + Roof_{ins} + SL + Pr_{design}}{Width} + \frac{Pr_{st}}{2} + \gamma_{conc}\ Depth$

$SBC_{ring\_2} = 167.56\ kPa$

Bearing Pressure Check, $SBC_{check\_3} = if(SBC_{ring\_2} \le SBC_{gross\_all}, "OK", "CHECK")$ $SBC_{check\_3} = "OK"$

Soil Bearing pressure under the tank, $SBC_{tank\_2} = Pr_{plt} + Pr_{st} + Pr_{d} + H_{soil}\ \gamma_{soil}$ $SBC_{tank\_2} = 198.9\ kPa$

Bearing Pressure Check, $SBC_{check\_4} = if(SBC_{tank\_2} \le SBC_{gross\_all}, "OK", "CHECK")$ $SBC_{check\_4} = "OK"$

LOAD COMBINATION # LC3 SW (corroded)+WL

Load under Ring Beam, $SBC_{ring\_3\_max} = \left(\frac{Metal_{cor}}{Width} + \gamma_{conc}\ Depth\right) + \frac{W_{mom}\left(0.5\ Ring_{OD}\right)}{\frac{\pi}{64}\left(Ring_{OD}^{4} - Ring_{ID}^{4}\right)}$

$SBC_{ring\_3\_max} = 111.94\ kPa$

Load under Ring Beam, $SBC_{ring\_3\_min} = \left(\frac{Metal_{cor}}{Width} + \gamma_{conc}\ Depth\right) - \frac{W_{mom}\left(0.5\ Ring_{OD}\right)}{\frac{\pi}{64}\left(Ring_{OD}^{4} - Ring_{ID}^{4}\right)}$

$SBC_{ring\_3\_min} = 106.33\ kPa$ (No tension)

Bearing Pressure Check, $SBC_{check\_5} = if(SBC_{ring\_3\_max} \le SBC_{gross\_all}, "OK", "CHECK")$ $SBC_{check\_5} = "OK"$

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LOAD COMBINATION # LC4 SW (corroded)+WL+VP

Load under Ring Beam, $SBC_{ring\_4\_max} = \left(\frac{Metal_{cor}}{Width} + \gamma_{conc}\ Depth + \frac{Vacuum}{Width}\right) + \frac{W_{mom}\left(0.5\ Ring_{OD}\right)}{\frac{\pi}{64}\left(Ring_{OD}^{4} - Ring_{ID}^{4}\right)}$

$SBC_{ring\_4\_max} = 117.66\ kPa$

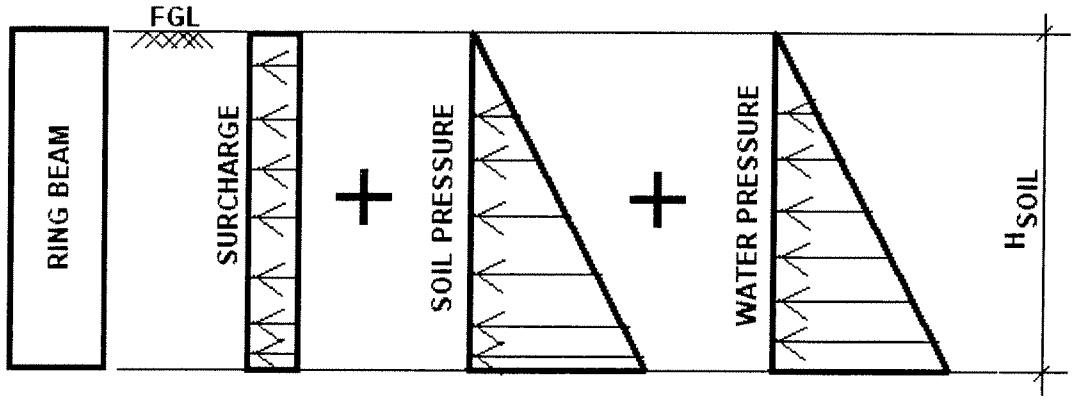
Load under Ring Beam, $SBC_{ring\_4\_min} = \left(\frac{Metal_{cor}}{Width} + \gamma_{conc}\ Depth + \frac{Vacuum}{Width}\right) - \frac{W_{mom}\left(0.5\ Ring_{OD}\right)}{\frac{\pi}{64}\left(Ring_{OD}^{4} - Ring_{ID}^{4}\right)}$

$SBC_{ring\_4\_min} = 112.05\ kPa$ (No tension)

Bearing Pressure Check, $SBC_{check\_6} = if\left(SBC_{ring\_4\_max} \le SBC_{gross\_all}, "OK", "CHECK"\right)$ $SBC_{check\_6} = "OK"$

Bearing pressure under ring beam and tank pad is compared for Load combination no. LC1 and found SBC values are close to each other. Hence, width of ring beam is ok. However, ring beam width shall be checked for anchor bolt.

3.5 Hoop tension Calculation for Ring Beam ULC1: 1.5*SW+1.5*PW+1.5*DP



LATERAL PRESSURE ON RING WALL

Pressure on wall due to weight of product and base plate, $L_{pres.1} = k_o\left(Pr_{plt} + Pr_{st}\right)$ $L_{pres.1} = 67.81\ kPa$

Pressure on wall due to design pressure inside the tank, $L_{pres.2} = k_o\left(Pr_d\right)$ $L_{pres.2} = 0.9\ kPa$

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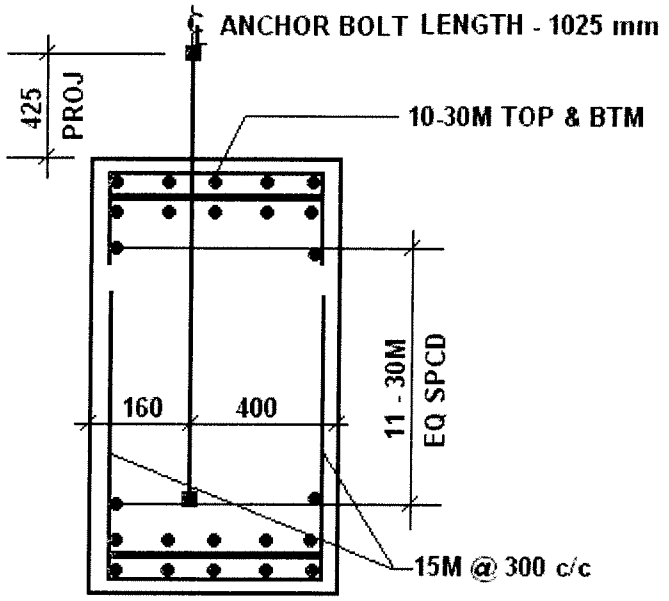
Pressure on wall due to compacted sand fill inside the ring, $L_{pres.3} = k_o \left[H_{soil} \left(\gamma_{soil} - \gamma_w \right) \right]$ $L_{pres.3} = 11.09\,kPa$

Pressure on wall due to water fill inside the ring, $L_{pres.4} = \left(H_{soil}\, \gamma_w \right)$ $L_{pres.4} = 21.56\,kPa$

Total ultimate Hoop Tension on Ring Beam, $HT = 1.5 \left(L_{pres.1} + L_{pres.2} + \frac{L_{pres.3}}{2} + \frac{L_{pres.4}}{2} \right) Depth \frac{ID}{2}$

$HT = 7699.05\,kN$

3.6 Reinforcement Calculation for Ring Beam



REBAR DETAIL OF RING WALL

3.6.1 Horizontal Rebar calculation,

Hoop tension in the ring wall due to surcharge and compacted soil pressure shall be taken care by Horizontal Re-bar only.

Area of re-bar required for Hoop tension, $A_{st\_H1} = \frac{HT}{\phi_s f_y}$ $A_{st\_H1} = 22644.26\,mm^2$

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Minimum horizontal rebar for vertical wall, (Refer cl#14.3.3) $A_{st\_H2} = 0.002\ Depth\ Width$ $A_{st\_H2} = 2640\ mm^2$

Minimum Horizontal re-bar required, $A_{st\_H\_reqd} = \max(A_{st\_H1}, A_{st\_H2})$ $A_{st\_H\_reqd} = 22644.26\ mm^2$

Use 42 - 30M horizontal rebar, distributed on the wall faces as shown in the above sketch,

Total Horizontal Rebar Provided, $A_{st\_H\_prov} = 42\ A_{30}$ $A_{st\_H\_prov} = 29400\ mm^2$

$Horizontal\_Rebar\_Check = if(A_{st\_H\_prov} \le A_{st\_H\_reqd}, "CHECK", "OK")$ $Horizontal\_Rebar\_Check = "OK"$

3.6.2 Vertical Rebar calculation,

Minimum vertical rebar for wall, (Refer cl#14.3.2) $A_{st\_V\_reqd} = 0.002\ 1000\ mm\ Width$ $A_{st\_V\_reqd} = 1200\ mm^2$

Use 15M @ 300 c/c vertcal rebar on each face of the wall,

Total vertical Rebar Provided, $A_{st\_V\_prov} = \frac{1000}{300} A_{15}\ 2$ $A_{st\_V\_prov} = 1333.33\ mm^2$

$Vertical\_Rebar\_Check = if(A_{st\_V\_prov} \le A_{st\_V\_reqd}, "CHECK", "OK")$ $Vertical\_Rebar\_Check = "OK"$

3.7 Anchor Bolt Checking for Ring Beam

Dia of Anchor Bolt, $d_{bolt} = 32\ mm$ Anchor Bolt Spacing, $Spacing = 3038\ mm$ $Projection = 425\ mm$

Bolt Edge distance, $Edge = 160\ mm$ $Check\_Edge = if(Edge < 4\ d_{bolt}, "CHECK", "OK")$ $Check\_Edge = "OK"$

Maximum Tension on Anchor Bolt, $T_{bolt} = 19.7\ kN$ Factor Tension, $T_f = 1.5\ T_{bolt}$ $T_f = 29.55\ kN$

Ductile failure of anchor bolt is checked for ultimate capacity of anchor bolt.

Ultimate tension for each bolt, $T_u = 165\ kN$ Provide Embedment length of bolt, $L_{emb\_bolt} = 600\ mm$

Tension capacity of concrete beam, $T_{conc} = (Width\ L_{emb\_bolt}\ 2)\ 0.3\ \lambda\ \phi_c \sqrt{\frac{f_c}{MPa}}\ MPa$ $T_{conc} = 709.85\ kN$

$Concrete\_capacity\_check = if(T_{conc} \ge T_u, "OK", "CHECK")$ $Concrete\_capacity\_check = "OK"$

Total Length of Bolt, $L_{bolt} = L_{emb\_bolt} + Projection$ $L_{bolt} = 1025\ mm$