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Design of Circular Overhead Water Tank, Modelling and Analysis Using Staad-Pro

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Abstract: ***Water tanks are frequently used for storing potable water. Due to inadequacy of water around the world, significance is given more on the water storage project. So water storage is very essential as it plays a vital role in everyday life. water tanks and Storage reservoirs are used to store water, petroleum products, liquid petroleum, and similar liquids. All tanks are analysed and designed as crack free structures to get rid off any leakage. This project provides a brief explanation of the theory underlying the manual analysis and design of an overhead circular water tank using the Working Stress Method (WSM) and software modeling and analysis using Stat-Pro.***
Keywords: Overhead Circular water tank, Staad-Pro, Population Forecsting Method, Limit State Method, Working State Method, IS Code

I. INTRODUCTION

Water is an essential necessity for human survival, and the distribution of enough water in a given region depends on the water tank's design. An elevated water tank is a type of water storage container used to maintain a water supply at a height high enough to pressurize a water distribution system. They were swept away by the wind. Damage of the important lifeline facility like elevated water tanks often results in significant hardships even after the occurrence of the disaster, claiming human casualties and economic loss to build environment. Investigating the effects of wind has been recognized as a necessary step to understand the natural hazards and its risk to the society in the long run. Because water towers rely on the elevation of water caused by gravity and hydrostatic pressure to force the water into home and industrial water distribution systems, they can provide water even when there is no electricity.

A. Objective

1) To make a study about design of water tank.
2) Design of Circular Overhead Water Tank by WSM and other staging members by LSM Method.
3) To make a study about the Analysis of Water Tank using Staad-Pro.
4) To make a study about the guidelines for the Design of Liquid retaining Structures according to IS Code.

II. METHODOLODY

In this project we have designed a Water Tank Manually and same analyzed on Staad-Pro software.

A. Data Collection

Details of data collection

1.	Capacity of tank	140000 L.
2.	Soil bearing capcity	125 KN/sq.m at minimum depth 3.00m
3.	Height of tank from ground	12m
4.	Grade of steel	fe500
5.	Grade of concrete	M30

	Ground water table	Maximum height of water table is assumed to be well below the foundation strata level hence no uplift pressure has been considered in the design footing.
6.	External force on tank	Basic wind speed 39m/s
7.	Free board	0.2m
8.	Width of gallery	1m
9.	Earthquake zone	III
10.	Use of water	Domestic purpose only
11.	Current population in year 2011	2480
12.	Population forcasting 2041	3500

B. Population Forcasting

We have forecasted the population by using Arithmetic Mean Method. We have collected the data from our proposed site and received data from 1979. Has been forecasted till 2041 by Arithmetic Progression.Population Forecasted is 3500 no of people.

III. DESIGN CRITERIA

A. Loads

1) *Dead Load:* The weight of all permanent construction including domes, ring beams, walls, stair case, slabs and foundation are considered. The unit weights of materials are in accordance with IS: 875-1987. The unit weight of Concrete (RCC),Soil,, Structural steel is taken as 25 kN/m3 ,18 kN/m3 ,78.5 kN/m3.
2) *Live Load:* The Live load on roof slab, walk way slab and staircase be 1.5 kN/m^2, 1.5 kN/m^2 and 2.0 kN/m^2 respectively.
3) *Water Load:* Weight of water due to gross volume is calculated and applied on bottom of container unit wt. of water is 10 kN/m^3
4) *Wind Load:* As per figure -1 IS: 875(PART-3)-1978) design wind pressure = 0.6Vz2 = 2117.01 N/m^2
5) *Earthquake load (EQ)*

It is in zone-III as per IS 1893 part1 2002
Seismic coefficient $\alpha h = \beta IFo(Sa/g)$
β , coefficient of depending upon soil foundation = 1
I, factor depending upon importance of factor = 1.5
So, seismic zone factor for average acceleration spectra = 0.16
Sa/g is considered as per CI 6.3.5,(IS 1893,part-1).

B. Structural design of RCC OHSR

Calculations

1) *Dimension of Tank*

- Diameter Of Tank D = 7.2m
- Radius= 3.6m
- Height =4m
- Thickness Of Tank Wall =170mm

2) *Wind load calculations*

By using IS 875 Part3 1987 Appexndix A.
Basic Wind Speed - 39 m/s.. ....Table 1
Pz =0.6 vz² - Design wind speed.
Pz = 0.527 kN/m²

3) Seismic Load Calculations

Using IS 1893 Part-1-2016 as the site exist in zone 3
all the parameters taken according to that.

Total Seismic weight on structure,
=4102.04+4102.04+4071.50
=12275.58KN

4) Circular Slab (Top roof)

Diameter D =7.2m
Thickness=170mm
L.L =1.5 Kn/m^2
M30 And Fe 500

- Total Load =5.75 Kn/m^2
- Max BM = -9.315 Kn.m

dreq = √(M/0.133fckb
=√(9.315 x 10^6/0.133 x 30 x 1000)
dreq =48.31mm
Provide D =150mm
Using 10mm bar and clear cover 15mm
d=150-15-10/2=130mm for bottom layer
And d=130-10=120mm for top layer

- steel reinforcement at centre (provide in mutually parallel direction)

Ast = 0.5fck/fy [1-√1-(4.6Mu)/(fckbd$^{2)}$] bd
Ast = 206.77 mm^2
Ast min = 0.12/100 x 1000 x 170
= 204mm^2
Provide min. reinforcement Using 10mm bar
Spacing= 1000ast/Ast
=380mm
Max. Spacing=3d= 3 x 120 =360mm or 450mm }less
Provide mesh reinforcement consisting of 10mm ø 360 c/c in mutually both direct at as bottom reinforcement.
At edge = no reinforcement (Mø)e= 0

5) Design of Top Ring Beam

- Load Of Slab = 4.25 Kn/m^2
- For hoop force
- T= w x R x (cosø - 1/ Hcosø)
  = 10.35kn/m
- Hoop stress = 10.35 x 10^3/1000 x 170
- = 0.06 <8N/mm^2 (8 N/mm^2 = permissble stress in concrete)Table 2, IS 3370 (part 2): 2009
- It is designed for hoop tension -

W = T cosø= 10.35 x cos0 = 10.35 KN/m
Total hoop tension in beam

W x D/2= $\frac{10.35 \times 7.2}{2}$ = 37.26 kN
AST for hoop tension
T/ σ_{st} = 37.26 x 10^3/130 = 286.61 mm ^{2} [σ_{st}= 130N /mm ^{2} Table 4, IS 3370 (part 2):2009]
σ_{st} = permissible stress in steel reinforcement use 12 mm Ø bar

To find out dimension of ring beam
σ_{ct} =T /Ag+(m-1) Ast <1.5
Ag= b x D.
Assume b=230 mm
m= 280/ σ_{cbc}= 280/3x10 = 9.33
σ_{cbc}= permissible stress in concrete [Table2 ,page3 ,IS 3370(Part 2): 2009]

σ_{ct} = 37.26x 10^3/230 x D +(9.33-1) x 286.61 <1.5
=37.26 x10^3 < 345D+ 3581.19
= 33678.808/345 < D
= 97.61<D
Consider D= 350mm
Provide minimum shear reinforcement

6) Design of Tank Wall
Max. hoop tension at base,
T=(γ_w × H × D)÷2
= (10×H×7.2)÷2
=72H÷2
T=36H KN/m
Ast=T ÷ σ_{st}
=(36÷130)×10^3 =276.92H mm^2

To find thickness of wall:-
σ_{ct}=T÷[Ag+(m-1)Ast]
T=36×4=144 KN
σ_{ct}=1.5
Ag=1000×t
(m-1)=9.83-1=8.3 m/s calculated at ring beam σ_{ct}=(144×10^3)÷[1000×t+(8.33×2×565.45)] <1.5
=(144×10^3)÷(1000t+9420.397)<1.5
144×10^3<1500t+14130.595
86.57<t
Provide t=200m at base and 150mm at top
Average thickness of wall =175mm
Distribution Steel:-
H÷3=4÷3=1.33m
Cantilever moment (m):-
M=[γ_w×H×(H/3)^2]÷6
=[10×4×(1.33)^2]÷6
M=11.84KN-m
Ast for moment=M÷(σst × j× d)
J=1-(K÷3) from the base slab
d=175-50=125mm

Ast for moment=$(11.84\times10^6)\div(130\times0.85\times125)$
=857.19mm²

7) Design of Base Slab

H =4m D =7.2 R=3.6m
Assume thickness=250mm
1) load (/m²area)
a) weight of water = 10 x V
= 10 x 1 x 4
= 6.25 KN
Total = 40 + 6.25=46.25KN
According IS 3370, part 4 table 20 pg 47
Moment= coefficient X PR² (Kgm/m)
At R = 0, at centre
Mr = Mt = +0.075 X 46.25 X 3.6²
= +4495KN.m
At support, where R=R
Mr= -0.125 x 46.25 x 3.6²
= -74.92KN.m
Mt = -0.025 x 46.25 x 3.6²
= -14.98KNm

Check for d (to check if dpro > dreq)
dreq = √ Mmax /R x b
= 74.92x10⁶/1.618x1000
(R is design constant)
dreq = 99.27 mm
dpro = depth of base
Slab 250 mm clear cover= 25 diameter=20
dprv =250-25-20/2
=215mm > dreq

1] Ast for - Mr at support

Ast = M/Sigma St x j x dprov
= 74.92 x 10⁶/115 x 0.85 x 215
= 3564.8 mm
Assume dia.= 20 mm
n = Ast/ ast = 3564.8/ π/4 x 20²
n = 6.80 = 7
Spacing= 1000/n =1000/7= 142.85=150 mm c/c.

Check for shear
V = P x 2R /2 = 46.25 x (2 x 3.6) /2 ......R= Radius
V = 166.5KN
Tau v = V/ bd_{prov} = 166.5 x 1000/ 1000 x 215
100 Ast / bd_{prov} =100 x [1000 x (π / 4) x 20²]/ 1000 x 215
= 1.46
τ_C = 0.4436 N/mm²
$\tau_v > \tau_C$.........Not safe

Provide a haunch of 20 mm size at the junction.

8) Design of Brace Beam

Assuming Beam Size
Square beam = 300x300 mm
Length between bracing= 3.8m
Total load = 2.5 + 2.25 + 5.375= 10.125Kn/m
Effective depth= 300- 50 = 250mm
Load calculation= Design load = 10.125 x 1.5
= 15.187KN/m
Moment calculation= Mu = $wxL^2/8$
= $15.187 \times (3.8)^2/8$
= 27.41KNm
$M_{ub} = 0.138 \times fck \times bd^2$
= 111.78×10^6 KNm.

Mub>Mu………hence singly reinforced beam

9) Design of Bottom Ring Beam

- Total vertical load = v_1= 31.875 KN/m.
- Horizontal force =H=v_1 cosø = 31.875KN

- Hoop tension due to vertical loads-
- Hg = H X D/2 =26.775 X 7.2/2
  = 96.39 KN.
- Hoop tension due to water pressure
- Hw= w x h x depth of beam x dia /2
  =10 x4 x 0.350 x 7.2/ 2. = 50.4 KN

- Total hoop tension = Hg + Hw = 96.39 + 50.4 = 146.79 kN
- Ast = $146.79 \times 10^3/150 = 978.6\ mm^2$

10) Design of Column

6 Columns equally spaced on 7.2m diameter circle
Height of Column=12m
Distance between Columns=3.8m
Diameter of Column=300mm
Pu=1095.845KN
Condition:-
Column is effectively held in position. and restrained against rotation in both ends.
Leffective =6m
Slenderness ratio =20mm>12mm
Minimum Eccentricity:
emin=34mm>20mm

Area of Reinforcement(Asc):-
$Ag=(\pi \div 4)\times(300)^2 = 70685.83\ mm^2$
Ac =70685.83-Asc
Puz=0.4fck.Ac + 0.67fy.Asc

$1095.845\times10^3 = [0.4\times30\times(70685.83-Asc)]+ (0.67\times500\times Asc)$
$Asc=766.61mm^2$
Assume 5% of steel,
Adopt 12mm ⌀ bar

Helical Reinforcement:-
Assume cover 40mm
Core Diameter(dc)=220mm
Area of Cover(Ac)=38013.27mm²
P=Pitch of Spiral ties
Vc=Volume of core =38013.27×P
Using 10mm & spirals (helical reinforcement)
Provide pitch of 30mm

11) Design of Footing
Area of Footing:-
As per IS code guidelines self wot of footing to taken 10% of column load
As load carried by column is 1095.85KN
Note: Design of square footing is done exactly in the same manner as PL was for square column

Side of square column:-
$b=0.717D=0.717\times300=215.1\approx220mm$
Note- As per IS recommendation for the purpose of design of footing for circular column the size of column is taken as 0.7170 times dia.

Area of Footing=Load ×SBC =1205.4295×125.12
SBC is taken as per test results on site
$1205.4295\div125.12 = 9.63\ m^2$
Side of square footing
$B= \sqrt{9.63}= 3.10 = 3.2m$

Therefore size of square footing for circular column
B x B= 3.2 x 3.2 m.
Net upward pressure (Po) =117.71KN
Step-Depth of Footing on the basis of BM
$M=Po(B\div8)(B-b)^2$
Now, Ultimate moment (Mu):-
$Mu=1.5\times M$
$=1.5\times395.97$
Mu=593.955KN-m

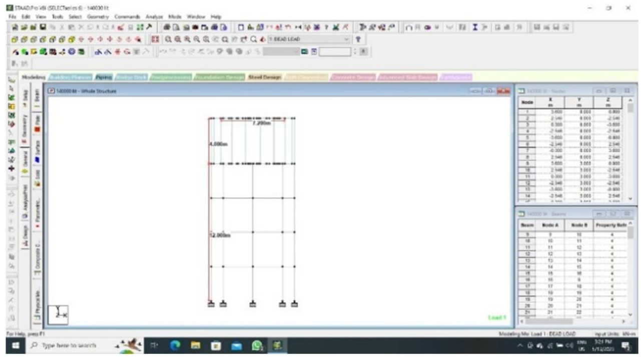
Dreq

$d=215.68mm\approx220mm$

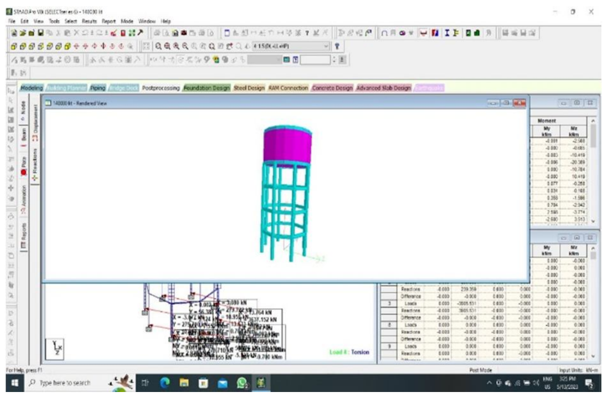
$Ast = 3582.34\ mm^2$

Footing has been checked for one way and two way shear, it has been safe.

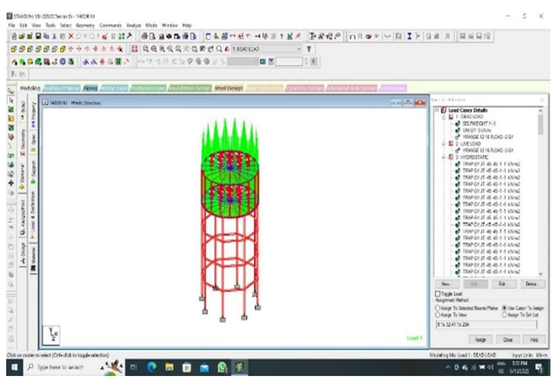
C. Modelling on Staad-Pro



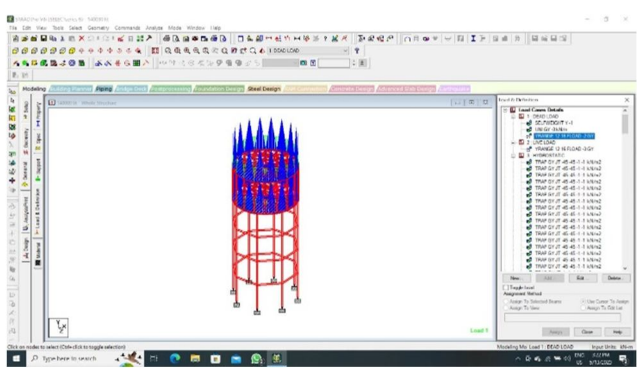
Column-450 mm, Ring Beam- 230 x 380, Slab- 170mm



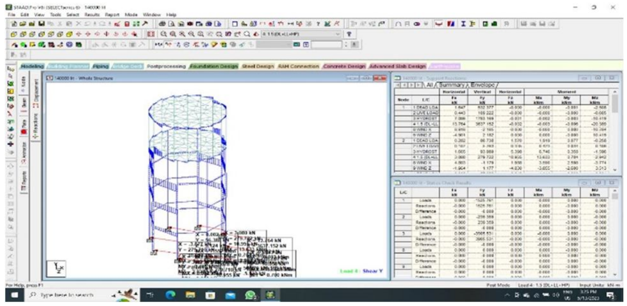
Created model by using material properties



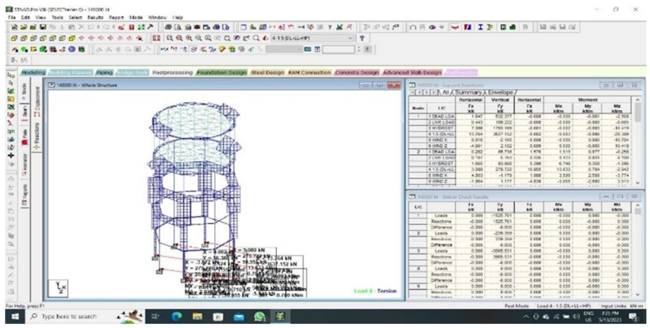
Dead Load Application



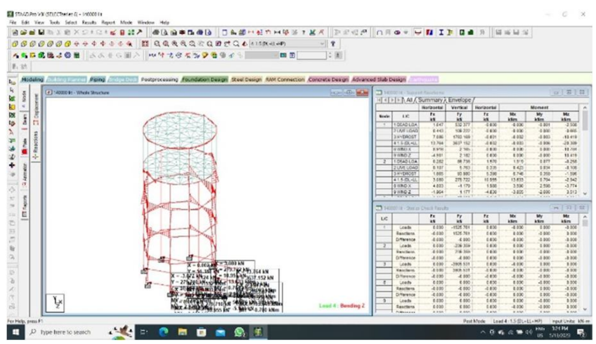
Hydrostatic Load Application



Shear Forces



Bending Moments



Torsional Moments

IV. CONCLUSION

1) The tank has been analyzed in STAAD Pro software.
2) In terms of the loads used, tank design is safe from software design.
3) We use circular water tanks for larger capacity while rectangular water tanks are used for smaller capacities. Since our proposed tank is of 1.40 lakh capacity we had prepared and analyzed the circular over head tank in STAAD Pro software.
4) Design of water tank is also done by manually by WSM and LSM method.
5) Design of water tank by manually and by using software are within limit and safe.

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