# 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 | $125 \mathrm{KN} / \mathrm{sq} . \mathrm{m}$ at minimum depth 3.00 m |
| 3. | Height of tank from ground | 12 m |
| 4. | Grade of steel | fe500 |
| 5. | Grade of concrete | M30 |


|  | Ground water table | Maximum height of water table is assumed to <br> be well below the foundation strata level <br> hence no uplift pressure has been considered <br> in the design footing. |
| :--- | :--- | :--- |
| 6. | External force on tank | Basic wind speed $39 \mathrm{~m} / \mathrm{s}$ |
| 7. | Free board | 0.2 m |
| 8. | Width of gallery | 1 m |
| 9. | Earthquake zone | III |
| 10. | Use of water | Domestic purpose only |
| 11. | Current population in year <br> 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 $25 \mathrm{kN} / \mathrm{m} 3,18 \mathrm{kN} / \mathrm{m} 3,78.5 \mathrm{kN} / \mathrm{m} 3$.
2) Live Load: The Live load on roof slab, walk way slab and staircase be $1.5 \mathrm{kN} / \mathrm{m}^{2}, 1.5 \mathrm{kN} / \mathrm{m}^{2}$ and $2.0 \mathrm{kN} / \mathrm{m}^{2}$ 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 $\mathrm{kN} / \mathrm{m}^{3}$
4) Wind Load: As per figure-1 IS: 875(PART-3)-1978) design wind pressure $=0.6 \mathrm{Vz2}=2117.01 \mathrm{~N} / \mathrm{m}^{2}$
5) Earthquake load (EQ)

It is in zone-III as per IS 1893 part 12002
Seismic coefficient $\alpha \mathrm{h}=\beta \mathrm{IFo}(\mathrm{Sa} / \mathrm{g})$
$\beta$, coefficient of depending upon soil foundation $=1$
I, factor depending upon importance of factor $=1.5$
So, seismic zone factor for average acceleration spectra $=0.16$
$\mathrm{Sa} / \mathrm{g}$ 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 $=7.2 \mathrm{~m}$
- Radius $=3.6 \mathrm{~m}$
- Height $=4 \mathrm{~m}$
- Thickness Of Tank Wall $=170 \mathrm{~mm}$

2) Wind load calculations

By using IS 875 Part 31987 Appexndix A.
Basic Wind Speed - $39 \mathrm{~m} / \mathrm{s}$.. $\qquad$ ..Table 1
$\mathrm{Pz}=0.6 \mathrm{vz}^{2}$ - Design wind speed.
$\mathrm{Pz}=0.527 \mathrm{kN} / \mathrm{m}^{2}$
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,
$=4102.04+4102.04+4071.50$
$=12275.58 \mathrm{KN}$
4) Circular Slab (Top roof)

Diameter $\mathrm{D}=7.2 \mathrm{~m}$
Thickness $=170 \mathrm{~mm}$
L. $\mathrm{L}=1.5 \mathrm{Kn} / \mathrm{m}^{2}$

M30 And Fe 500

- Total Load $=5.75 \mathrm{Kn} / \mathrm{m}^{2}$
- Max BM =-9.315 Kn.m
dreq $=\sqrt{ }(\mathrm{M} / 0.133 \mathrm{fckb}$
$=\sqrt{ }\left(9.315 \times 10^{6} / 0.133 \times 30 \times 1000\right)$
dreq $=48.31 \mathrm{~mm}$
Provide D $=150 \mathrm{~mm}$
Using 10 mm bar and clear cover 15 mm
$\mathrm{d}=150-15-10 / 2=130 \mathrm{~mm}$ for bottom layer
And d=130-10=120mm for top layer
- steel reinforcement at centre (provide in mutually parallel direction)

Ast $=0.5 \mathrm{fck} / \mathrm{fy}\left[1-\sqrt{1}-(4.6 \mathrm{Mu}) /\left(\mathrm{fckbd}^{2}\right] \mathrm{bd}\right.$
Ast $=206.77 \mathrm{~mm}^{2}$
Ast $\min =0.12 / 100 \times 1000 \times 170$
$=204 \mathrm{~mm}^{2}$
Provide min. reinforcement Using 10 mm bar
Spacing $=1000$ ast $/$ Ast

$$
=380 \mathrm{~mm}
$$

Max. Spacing $=3 \mathrm{~d}=3 \times 120=360 \mathrm{~mm}$ or 450 mm$\}$ less
Provide mesh reinforcement consisting of $10 \mathrm{~mm} \varnothing 360 \mathrm{c} / \mathrm{c}$ in mutually both direct at as bottom reinforcement.
At edge $=$ no reinforcement $(\mathrm{M} \varnothing) \mathrm{e}=0$
5) Design of Top Ring Beam

- Load Of Slab $=4.25 \mathrm{Kn} / \mathrm{m}^{2}$
- For hoop force
- $\mathrm{T}=\mathrm{w} \times \mathrm{R} \times(\cos \varnothing-1 / \mathrm{H} \cos \varnothing)$
$=10.35 \mathrm{kn} / \mathrm{m}$
- Hoop stress $=10.35 \times 10^{3} / 1000 \times 170$
- $=0.06<8 \mathrm{~N} / \mathrm{mm}^{2}\left(8 \mathrm{~N} / \mathrm{mm}^{2}=\right.$ permissble stress in concrete)Table 2, IS 3370 (part 2): 2009
- It is designed for hoop tension -
$\mathrm{W}=\mathrm{T} \cos \varnothing=10.35 \mathrm{x} \cos 0=10.35 \mathrm{KN} / \mathrm{m}$
Total hoop tension in beam
$\mathrm{W} \times \mathrm{D} / 2=\frac{10.35 \mathrm{x} 7.2}{2}=37.26 \mathrm{kN}$
AST for hoop tension
$\mathrm{T} / \sigma_{\mathrm{st}}=37.26 \times 10^{3} / 130=286.61 \mathrm{~mm}^{2} \quad\left[\sigma_{\mathrm{st}}=130 \mathrm{~N} / \mathrm{mm}^{2}\right.$ Table 4, IS 3370
( part 2):2009]
$\sigma_{\mathrm{st}}=$ permissible stress in steel reinforcement use $12 \mathrm{~mm} \emptyset$ bar
To find out dimension of ring beam
$\sigma_{\mathrm{ct}}=\mathrm{T} / \mathrm{Ag}+(\mathrm{m}-1)$ Ast $<1.5$
$\mathrm{Ag}=\mathrm{b} \times \mathrm{D}$.
Assume $\mathrm{b}=230 \mathrm{~mm}$
$\mathrm{m}=280 / \sigma_{\mathrm{cbc}}=280 / 3 \times 10=9.33$
$\sigma_{\text {cbc }}=$ permissible stress in concrete [Table2 ,page3 ,IS 3370(Part 2): 2009]
$\sigma_{\mathrm{ct}}=37.26 \times 10^{3} / 230 \times \mathrm{D}+(9.33-1) \times 286.61<1.5$
$=37.26 \times 10^{3}<345 \mathrm{D}+3581.19$
$=33678.808 / 345<\mathrm{D}$
$=97.61<\mathrm{D}$
Consider $\mathrm{D}=350 \mathrm{~mm}$
Provide minimum shear reinforcement

6) Design of Tank Wall

Max. hoop tension at base,

$$
\begin{aligned}
& \mathrm{T}=\left(\gamma_{\mathrm{w}} \times \mathrm{H} \times \mathrm{D}\right) \div 2 \\
& =(10 \times \mathrm{H} \times 7.2) \div 2 \\
& =72 \mathrm{H} \div 2 \\
& \mathrm{~T}=36 \mathrm{HNN} / \mathrm{m} \\
& \text { Ast }=\mathrm{T} \div \sigma_{\mathrm{st}} \\
& =(36 \div 130) \times 10^{3}=276.92 \mathrm{H} \mathrm{~mm}^{2}
\end{aligned}
$$

To find thickness of wall:-

```
\sigmact}=\textrm{T}\div[\textrm{Ag}+(\textrm{m}-1)\textrm{Ast}
T=36\times4=144 KN
\sigmact}=1.
Ag=1000xt
(m-1)=9.83-1=8.3 m/s calculated at ring beam }\mp@subsup{\sigma}{\textrm{ct}}{}=(144\times1\mp@subsup{0}{}{3})\div[1000\times\textrm{t}+(8.33\times2\times565.45)]<1.
=(144\times103)\div(1000t+9420.397)<1.5
144\times103<1500t+14130.595
86.57<t
Provide t=200m at base and 150mm at top
Average thickness of wall =175mm
Distribution Steel:-
H}\div3=4\div3=1.33\textrm{m
Cantilever moment (m):-
M=[\mp@subsup{\gamma}{w}{}\timesH\times(H/3)}\mp@subsup{)}{}{2}]\div
=[10\times4\times(1.33)2}]\div
M=11.84KN-m
Ast for moment=M}\div(\sigmast\timesj\timesd
J=1-(K\div3) from the base slab
d=175-50=125mm
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Ast for moment=( $\left.11.84 \times 10^{\circ}\right) \div(130 \times 0.85 \times 125)$
$=857.19 \mathrm{~mm}^{2}$
7) Design of Base Slab
$\mathrm{H}=4 \mathrm{~m} \quad \mathrm{D}=7.2 \mathrm{R}=3.6 \mathrm{~m}$
Assume thickness $=250 \mathrm{~mm}$

1) $\operatorname{load}\left(/ \mathrm{m}^{2}\right.$ area)
a) weight of water $=10 \times \mathrm{V}$
$=10 \times 1 \times 4$
$=6.25 \mathrm{KN}$
Total $=40+6.25=46.25 \mathrm{KN}$
According IS 3370, part 4 table 20 pg 47
Moment $=$ coefficient X $\mathrm{PR}^{2}(\mathrm{Kgm} / \mathrm{m})$
At $\mathrm{R}=0$, at centre
$\mathrm{Mr}=\mathrm{Mt}=+0.075 \mathrm{X} 46.25 \times 3.6^{2}$
$=+4495 \mathrm{KN} . \mathrm{m}$
At support, where $\mathrm{R}=\mathrm{R}$
$\mathrm{Mr}=-0.125 \times 46.25 \times 3.6^{2}$
$=-74.92 \mathrm{KN} . \mathrm{m}$
$\mathrm{Mt}=-0.025 \times 46.25 \times 3.6^{2}$
$=-14.98 \mathrm{KNm}$

> Check for d (to check if dpro $>$ dreq)
> dreq $=\sqrt{ } \mathrm{Mmax} / \mathrm{R} \times$ b
> $=74.92 \times 10^{6} / 1.618 \times 1000$
> $(\mathrm{R}$ is design constant $)$
> dreq $=99.27 \mathrm{~mm}$
> dpro $=$ depth of base
> Slab 250 mm clear cover $=25$ diameter $=20$
> dprv $=250-25-20 / 2$
> $=215 \mathrm{~mm}>$ dreq

1] Ast for - Mr at support
Ast $=\mathrm{M} /$ Sigma St x j dprov
$=74.92 \times 10^{6} / 115 \times 0.85 \times 215$
$=3564.8 \mathrm{~mm}$
Assume dia. $=20 \mathrm{~mm}$
$\mathrm{n}=$ Ast $/$ ast $=3564.8 / \pi / 4 \times 20^{2}$
$\mathrm{n}=6.80=7$
Spacing $=1000 / \mathrm{n}=1000 / 7=142.85=150 \mathrm{~mm} \mathrm{c} / \mathrm{c}$.

Check for shear
$\mathrm{V}=\mathrm{P} \times 2 \mathrm{R} / 2=46.25 \times(2 \times 3.6) / 2 \ldots . . \mathrm{R}=$ Radius
$\mathrm{V}=166.5 \mathrm{KN}$
Tau v $=\mathrm{V} /$ bd $_{\text {prov }}=166.5 \times 1000 / 1000 \times 215$
100 Ast $/ \mathrm{bd}_{\text {prov }}=100 \times\left[1000 \times(\pi / 4) \times 20^{2}\right] / 1000 \times 215$
$=1.46$
$\tau_{\mathrm{C}}=0.4436 \mathrm{~N} / \mathrm{mm}^{2}$
$\tau_{\mathrm{v}}>\tau_{\mathrm{C}} \ldots \ldots . .$. .Not safe

Provide a haunch of 20 mm size at the junction.
8) Design of Brace Beam

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

Mub>Mu..........hence singly reinforced beam
9) Design of Bottom Ring Beam

- Total vertical load $=\mathrm{v}_{1}=31.875 \mathrm{KN} / \mathrm{m}$.
- Horizontal force $=\mathrm{H}=\mathrm{v}_{1} \cos \varnothing=31.875 \mathrm{KN}$
- Hoop tension due to vertical loads-
- $\mathrm{Hg}=\mathrm{H} \mathrm{X} \mathrm{D} / 2=26.775 \times 7.2 / 2$ $=96.39 \mathrm{KN}$.
- Hoop tension due to water pressure
- $H w=w x h x$ depth of beam $\times \operatorname{dia} / 2$ $=10 \times 4 \times 0.350 \times 7.2 / 2 .=50.4 \mathrm{KN}$
- Total hoop tension $=\mathrm{Hg}+\mathrm{Hw}=96.39+50.4=146.79 \mathrm{kN}$
- Ast $=146.79 \times 10^{3} / 150=978.6 \mathrm{~mm}^{2}$

10) Design of Column

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

Area of Reinforcement(Asc):-
$\mathrm{Ag}=(\pi \div 4) \times(300)^{2}=70685.83 \mathrm{~mm}^{2}$
$\mathrm{Ac}=70685.83-\mathrm{Asc}$
Puz=0.4fck.Ac +0.67 fy.Asc
$1095.845 \times 10^{3}=[0.4 \times 30 \times(70685.83-$ Asc $)]+(0.67 \times 500 \times$ Asc $)$
Asc $=766.61 \mathrm{~mm}^{2}$
Assume 5\% of steel,
Adopt $12 \mathrm{~mm} \varnothing$ bar

Helical Reinforcement:-
Assume cover 40 mm
Core Diameter (dc) $=220 \mathrm{~mm}$
Area of Cover(Ac) $=38013.27 \mathrm{~mm}^{2}$
$\mathrm{P}=$ Pitch of Spiral ties
$\mathrm{Vc}=$ Volume of core $=38013.27 \times \mathrm{P}$
Using 10 mm \& spirals (helical
reinforcement)
Provide pitch of 30 mm

## 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 1095.85 KN
Note: Design of square footing is done exactly in the same manner as PL was for square column

Side of square column:-
$\mathrm{b}=0.717 \mathrm{D}=0.717 \times 300=215.1 \approx 220 \mathrm{~mm}$
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 $\times$ SBC $=1205.4295 \times 125.12$
SBC is taken as per test results on site
$1205.4295 \div 125.12=9.63 \mathrm{~m}^{2}$
Side of square footing
$B=\sqrt{ } 9.63=3.10=3.2 \mathrm{~m}$

Therefore size of square footing for circular column
B $\times \mathrm{B}=3.2 \times 3.2 \mathrm{~m}$.
Net upward pressure ( Po ) $=117.71 \mathrm{KN}$
Step-Depth of Footing on the basis of BM
$\mathrm{M}=\mathrm{Po}(\mathrm{B} \div 8)(\mathrm{B}-\mathrm{b})^{2}$
Now, Ultimate moment (Mu):-
$\mathrm{Mu}=1.5 \times \mathrm{M}$
$=1.5 \times 395.97$
$\mathrm{Mu}=593.955 \mathrm{KN}-\mathrm{m}$

Dreq
$\mathrm{d}=215.68 \mathrm{~mm} \approx 220 \mathrm{~mm}$

Ast $=3582.34 \mathrm{~mm}^{2}$

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- $230 \times 380$, Slab- 170mm


Dead Load Application



## 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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