DESIGN OF OVERHEAD CIRCULAR WATER TANK

M. Gowtham*1, Rajesh.P*2, SK. Syfuddin*3, T. Sai Nikhil*4,
Dr. S.R.K. Reddy*5

*1,2,3,4Under Graduate Students, Department Of Civil Engineering, Seshadri Rao Gudlavalleru Engineering College, Gudlavalleru, Andhra Pradesh, India.
*5Adjunct Professor, Dept. Of Civil Engineering, Seshadri Rao Gudlavalleru Engineering College, Gudlavalleru, Andhra Pradesh, India.

DOI : https://www.doi.org/10.56726/IRJMETS38861

ABSTRACT

Water tanks are widely used for storing water. Water storage is very important as it plays a vital role in everyday life. Storage reservoirs and water tanks are used to store water and liquids like petroleum etc. Overhead tanks are to be constructed for distributing water to the people of village or town maintaining certain head of water. In this project, a two lakh liters capacity circular overhead tank is chosen for analysis and design of various structural elements of the tank is carried out.

I. INTRODUCTION

Storage reservoirs and overhead tank are used to store water, liquid petroleum, petroleum products and similar liquids. These structures are made of masonry, steel, reinforced concrete and pre stressed concrete. Out of these, masonry and steel tanks are used for smaller capacities. The cost of steel tanks is high and hence they are rarely used for water storages. Reinforced concrete tank is high and hence they are rarely used for water storages. Reinforced concrete tanks are very popular because, besides the construction and designs being simple, they are cheap, monolithic in nature and can be made leak proof.

The parameters required to design an elevated water tank are location, capacity, shape of water tank; and analysis of different structural elements of circular water tank and staging & foundation against gravity and wind loads. It is an overhead circular tank with staging height 12 meters supported by 8 columns properly connected with bracing at 3 levels as mentioned below.

SOURCE OF WATER SUPPLY

The various sources of water can be classified into two categories:

❖ Surface sources –
  • Ponds and lakes
  • Streams and rivers
  • Storage reservoir
  • Oceans
❖ Sub surface sources –
  • Springs
  • Infiltration wells
  • Wells and tube wells

II. METHODOLOGY

DESIGNING

• Top dome
• Ring beam
• Vertical wall
• Bottom slab
• Columns
• Brace beams
Footing

III. ANALYSIS AND DESIGN OF TANK

- Diameter of the cylindrical portion,

\[ D = \sqrt{\left(\frac{4\times V}{\pi\times H}\right)} \]

Where, \( D \) = diameter
\( V \) = volume of tank (capacity = 200 m³)
\( H \) = height of water (3.5 m)

\[ D = \sqrt{\left(\frac{4\times 200}{\pi\times 3.5}\right)} \]

\[ D = 8.56 \text{ m} \]

Radius of cylinder portion, \( R = 4.5 \text{ m} \)

\( h_{1} = 0.2 \times 0.9 = 1.8 \)

\( D = 9 \text{ m} \)

Thickness of the wall, \( t = 100 \text{ mm} \)

DESIGN OF TOP DOME

(a) Meridional force \( (T_1) \)

\[ T_1 = \frac{W \times R}{1 + \cos \theta} \]

Self weight = 0.10 \times 25 = 2.5 KN/m²

\[ W = 4 \text{ KN/m²} \]

\[ R = \frac{\left(\frac{D}{2}\right)^2 + h^2}{2 \times h} = \frac{\left(\frac{9}{2}\right)^2 + (1.8)^2}{2 \times 1.8} \]

\[ R = 6.52 \text{ m} \]

\[ T_1 = \frac{W \times R}{1 + \cos \theta} = \frac{4 \times 6.52}{1 + 0.724} \]

\[ T_1 = 15.13 \text{ KN/m} \]

Meridional stress \( = \frac{15.13 \times 10^3}{1000 \times 100} = 0.151 \text{ N/mm}^2 \)

In IS : 3370 (part2), table2, for M-30 concrete
Permissible stress in concrete = 8 N/mm²

\[ \therefore 0.151 < 8 \text{ N/mm}^2 \ldots \text{safe} \]

Provide 0.24% min reinforcement
\[ \text{Ast} = \frac{0.24}{100} \times 1000 \times 100 = 240 \text{ mm}^2 \]

Provide 8 Ф@ 200 mm c/c (ast = 251 mm²)

For Hoop Force \( (T_2) \)

\[ T_2 = w \times R \left(\cos \theta - \frac{1}{1 + \cos \theta}\right) = 4 \times 6.252 \left[0.724 - \frac{1}{1 + 0.724}\right] \]

\[ T_2 = 3.6 \text{ KN/m} \]

Hoop stress \( = \frac{3.6 \times 10^3}{1000 \times 100} = 0.036 \)

0.036 < 8 N/mm² safe

Provide min reinforcement (0.24%)
provide 8 Ф@ 200 mm c/c (ast=251 mm²)
DESIGN OF TOP RING BEAM

It is designed for hoop tension

\[ W = T \cos \theta = 15.13 \times 0.724 \]

\[ W = 10.95 \text{ KN/m} \]

\[ \therefore \text{ Total hoop tension in beam} \]

\[ W = 10.95 \times \frac{D}{2} \]

\[ = 49.275 \text{ KN} \]

\[ \therefore \text{Ast for hoop tension} \]

\[ \frac{T}{\sigma_{st}} = \frac{49.275 \times 10^3}{130} \]

\[ = 380 \text{ mm}^2 \]

Provide 12 Φ @ 150 mm c/c (ast = 400 mm²)

To find out dimension of ring beam (IS : 456, pg - 80)

\[ \sigma_{ct} = \frac{T}{Ag + (m-1)Ast} \]

\[ = \frac{49.275 \times 10^3}{250 \times D + (9.33-1) \times 753} \]

\[ \frac{49.275 \times 10^3}{250 \times D + 6272.49} < 1.5 \]

\[ 49.275 \times 10^3 < 375D + 9408.73 \quad : \quad 106.31 < D \]

Considering D = 300 mm

Size of the beam = 250 mm x 300 mm

Provide min shear reinforcement

8 mm Φ - 2 legged vertical stirrups

Is : 456-2000, pg-48

\[ S_v = 0.87 \times f_y \times a_s \times v \times 0.4 \times b \times v = 362.96 \text{ mm} \]

Spacing limits:

(a) \[ 0.75 \times D = 225 \text{ mm} \]

(b) \[ 300 \text{ mm} \]

\[ \therefore \text{ provide 8 mm Φ - 2 legged vertical stirrups at 225 mm c/c} \]

![Ring beam](image1.png)

DESIGN OF TANK WALL

Max hoop tension at base

\[ T = \frac{y_{g} \times H \times D}{2} = \frac{10 \times H \times 9}{2} = 45H \text{ KN/m} \]

\[ \text{Ast} = \frac{T}{\sigma_{st}} = \frac{45H \times 10^3}{130} = 346.15 \text{ H} \]

\[ \text{Ast} = 346.15 (3.7) \]

Area of each face is = 1280.755/2

\[ = 640.377 \]
10 Ø @ 110 mm c/c (Ast=714 mm^2)

**To find out thickness of wall**

\[
\sigma_c t = \frac{R}{A_p + (m-1)A_{st}}
\]

- \( \frac{222 \times 10^3}{1000+(8.33)\times(2\times714)} = 1.5 \)
- \( 222 \times 10^3 < 1500 \times t + 17842.86 \)
- \( 175 = t \)

Provide \( t = 175 \) mm

**Distribution steel**

- \( H/3 = 4/3 = 1.23 \) m

Cantilever moment (m) = \( \frac{wH(H^2)}{12} = 10.086 \) KN.m

\[
A_{st \text{ for moment}} = \frac{M}{\sigma_{st} \times f \times d}
\]

\[
= \frac{10.086 \times 10^6}{130 \times 0.861 \times 125}
\]

\( = 720.879 \) mm^2

∴ provide 12mm Ø @ 130 mm c/c (Ast = 746.9 mm^2)

**DESIGN OF BOTTOM SLAB**

**Loads**

- D.L of slab = 250 × 20 = 5000 N/m²
- Weight of water = 3700 N/m²
- Total = 8700 N/m²

Assume fixity at the ends

Maximum negative radius moment = \( \frac{Qr^2}{8} = \frac{8700 \times (4.5)^2}{8} = 22021.875 \) Nm

Maximum bending moment

Equating the m.r to the bending moment

\[ 1.333 \times 1000 \times d^2 = 35573.2 \times 1000 \]

\( d = 163.3 \) mm

Providing an effective cover of 40 mm effective depth available

\( = 200-40 = 160 \) mm

\[
A_{st} = \frac{22021875}{115 \times 0.84 \times 160} = 1424 \text{ mm}^2
\]

Spacing of 16mm Ø bars = \( \frac{201 \times 1000}{1424} = 141 \text{ mm} \)

Providing 16mm Ø bars@13mm/c

This is the radial steel at the radial steel at top and is provide 0.2 dia

\( = 0.2 \times 9 \)

= 1.8 m from the edge

Maximum positive radial moment = \( 22021875/2 = 11010937.5 \) Nmm

Maximum circumference moment is also equal to 11010937.5 Nmm

\[
A_{st} = \frac{11010937.5}{125 \times 0.861 \times 160} = 640.8 \text{ mm}^2
\]

Spacing of 12mm Ø bars = \( \frac{113 \times 1000}{640.1} = 176.53 \) mm

Spacing of 12mm Ø bars@150mm c/c in each principal direction.

**DESIGN OF COLUMN**

8 columns
Height of column = 12 m
Diameter of column = 300 mm
Total load on ring beam = 149.53 KN
\[ W = \pi \times D \times \pi \times 9 \times 149.53 = 4227.86 \text{ KN.} \]
Vertical load on each column = \( P = \frac{4227.86}{8} \)
= 528.48 KN
Factored load = 1.5 \times P = 1.5 \times 528.48 = 792.72 KN
Condition = column effectively held in position and restrained against rotation in both ends.
L effective = 0.5 \times L = 0.5 \times 12 = 6 m
Slenderness ratio = \( \frac{L_{\text{effective}}}{D} = \frac{6 \times 10^3}{300} \) = 20.61 > 12 mm
Minimum eccentricity \( e_{\text{min}} = \frac{L}{500} + \frac{D}{300} = \frac{12000}{500} + \frac{300}{300} = 34 > 20 \) mm
\( \frac{e_{\text{min}}}{D} = 0.005 \)
\( \frac{34}{300} = 0.13 > 0.05 \)
Member is subjected to axial force or uniaxial bending (Assumed uniaxial bending)
Area of reinforcement = \( A_{\text{sc}} \)
\[ P_u z = 0.45 f_{ck} A_c + 0.75 f_y A_{\text{sc}} \]
\[ 792.72 \times 10^3 = 0.45 \times 30 \times (70685.83 - A_{\text{sc}}) + 0.75 \times 415 A_{\text{sc}} \]
\[ A_{\text{sc}} = 2242.09 \text{ mm}^2 = 2245 \text{ mm}^2 \]

DESIGN OF BRACINGS:
Square beam = 300\times300 mm
Length between bracing = 4 m
Self weight of slab = 25\times0.1 = 2.5 KN
Self weight of beam = 0.3\times0.3\times25 = 2.25 KN
Live load = 2.5 KN
Total load = 2.5 +2.5+2.25 = 7.25 KN/m
Effective depth = 300 - 50 = 250 mm
Load calculation
Design load = 7.25\times1.5 = 10.875 KN/m
Moment calculation = \( M_u = \frac{W L^2}{8} = \frac{10.875 \times 4^2}{8} = 13.00 \text{ KN.m} \)
\[ M_{ub} = 0.138 f_{ck} b d^2 = 0.138 \times 30 \times 300 \times 300^2 = 111.78 \times 10^6 \text{ KN} \]
\[ M_{Mb} = 0.87 f \]
\[ A_{st} = 1350.62 \text{ mm} \]
Assume 4 - 25 mm Ø bar
Shear reinforcement

\[ V_u = \frac{WL^2}{2} = \frac{10.875 \times 4^2}{2} = 51.985 \text{ KN} \]
\[ \tau_v = \frac{Vu}{bd} = \frac{51.985 \times 10^3}{300 \times 300} = 0.577 \text{ N/mm}^2 \]
\[ \text{Pt } \% = 100 \times \frac{A_{st}}{bd} \]
\[ = 100 \times \frac{1350.623 \times 1000}{300} = 1.500 \% \]

From table 19, IS 4262-2000
\[ \tau_c = 0.76 \text{ N/mm} \]

Hence \( \tau_c > \tau_v \) the section is safe in shear yet minimum shear reinforcement is provided for beam.

Assuming 8 mm \( \phi \) bar 2 legged
\[ S_v = \frac{0.87 \times A_{sv} \times f_y}{0.4 \times b} = \frac{0.87 \times 415 \times 100 \times 0.53}{0.4 \times 300} = 302.472 \text{ mm} = 300 \text{ mm} \]

DESIGN OF FOOTING

- As per IS code guideline self weight of footing is taken 10% of column load.

\[ W = \text{load carried by column} + \text{self weight of footing} \]
\[ W = 792.72 + \frac{10}{100} \times 792.72 = 871.992 \text{ KN} \]

Load on foundation soil.

Note: as per IS recommendation for the purpose of design of circular column of size 0.7170 in diameter given circle is taken.

Design of square footing is done exactly in the same manner as it was for square column.

- Side of square column =
  \[ b = 0.717 \times D = 0.717 \times 300 = 215.1 = 220 \text{ mm} \]

Area of footing = \( \frac{\text{Load}}{S_{BC}} \)
\[ = 792.72 \times 200 = 7.946 \text{ m}^2 \]

Side of square footing = \( B = 2.81 = 3 \text{ m} \)

Therefore, size of square footing for circular column
\[ B \times B = 3 \times 3 \text{ m} \]

Factored soil pressure on footing =
\[ q_u = \text{factored load} / \text{actual area} \]
\[ = \frac{792.72}{3 \times 3} = 160.525 \text{ KN/m} \]

Depth of footing by bending moment criteria = Critical section for BM is taken as face of column
\[ M_u = \frac{q_u \times B \times (B - b)^2}{8} \]
\[ = \frac{481.575 \times (3 - 0.22)^2}{8} = 465.22 \text{ KN.m} \]
B.M at critical section

Note: in equilibrium condition, Mu = Mu lim

\[ \text{Mu lim} = 0.138 \times \text{fck} \times d^2 \]

445.22 \times 10^6 = 0.138 \times 30 \times 3000d

\[ d = 193.538 \text{ mm} = 194 \text{ mm} \]

Increase d 1.75 to 2.25 times to make depth of footing safe in shear action.

\[ d = 2 \times 194 = 388 \text{ mm} = 390 \text{ mm} \]

Check depth of footing against one way shear action, the critical section for one way shear is at a distance d from force of column.

\[ V_u = q_u \times B \times \left( \frac{b - d}{2} - d \right) \]

\[ = 481.575 \times \left( \frac{3 - 0.22}{2} - 0.390 \right) = 481.575 \text{ KN} \]

Factored S.F at critical section

Shear stress developed at critical section

\[ \tau_v = \frac{V_u}{bd} \]

\[ = \frac{481.575 \times 10^3}{3000 \times 390} = 0.41 \text{ N/mm}^2 \]

Shear strength of concrete

It depends upon grade of concrete and percent age of steel. Assume Pt\% = 0.5 %

Value of \( \tau_c \) from table 19, IS 426-2000

\( \tau_c = 0.50 \text{ N/mm}^2 \)

As, \( \tau_c > \tau_v \) hence depth of footing in safe again stone way shear.

Check depth of footing for bending shear action,

The critical section for punching shear is at ‘a’ distance \( \frac{d}{2} \) from face of the column,

\[ a = \frac{d}{2} + \frac{d}{2} + b = \frac{390}{2} + \frac{390}{2} + 220 = 610 \text{ mm} \]

\[ V_u' = q_u \times (B^2 - a^2) = 160.52 \times (3^2 - 0.61^2) \]

\[ = 1384.99 \text{ KN} \]

Shear stress developed by punching shear =

\[ bo = \text{perimeter of critical section} = 4 \times 610 = 2440 \text{ mm} \]

\[ \tau_v = \frac{V_u'}{bd} = \frac{1384.99 \times 10^3}{2440 \times 220} = 2.58 \text{ N/mm}^2 \]

Shear strength of concrete against punching =

\( \tau_c = K \times 0.2 \times fck = 0.50 \text{ N/mm}^2 \)

Where,

\( K \) = depends upon depth of footing slab and for \( d > 300 \text{ mm} = 1 \)

\[ \tau_c = 0.2 \times 30 = 1.095 \text{ N/mm}^2 \]

Area of steel = \( Mub = 0.87 \text{ fck} \times Ast \times \frac{d - fyxAst}{fck \times b} \)

\[ 456.22 \times 106 = 0.87 \times 415 \times Ast \times \frac{390 - 415 \times Ast}{300 \times 3000} \]

\[ Ast = 3374.62 \text{ mm}^2 \] Now using 18 mm \( \varnothing \) bar

Spacing = \[ \frac{B \times ast}{Ast} = \frac{3000 \times 256.46}{3374.62} = 226.22 \approx 220 \text{ mm} \]
IV. RESULTS AND DISCUSSION

- Number of columns = 8
- Diameter of tank = 9 m
- Load on top dome = 4 KN/
- Load due to ring beam = 1.5 KN/
- Load on each column = 528.48 KN
- Diameter of column = 300 mm
- Total height of the structure = 17.5

V. CONCLUSION

Elevated circular tanks shall be designed to distribute water to the people of villages or towns. Circular shaped Elevated water tanks are economical compared to rectangular or square tanks, as the thickness of wall can be reduced.

Bracings shall be designed for horizontal loads due to wind or earthquake for 2 lakh litre capacity, 9 m inside diameter and 175 mm thick vertical wall are obtained.

When the structures rest on sandy/ Murrum soils, raft foundation are chosen. In the design M30 grade concrete and Fe 415 steel are used.

The tank is assume rusting on sandy/ Murrum soil and accordingly isolated tutting are designed.
VI. REFERENCES


