

COMPARATIVE STUDY ON THE DESIGN OF ELEVATED SPHERICAL CONCRETE WATER TANK

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ABSTRACT

Water is essential for all living things to survive. Water provision is critical in areas where water is scarce. Water supplied to such locations is kept in a tank. This sort of water tank is built publicly. People get water from tanks via pipes. These tanks come in a variety of shapes, including spherical and rectangular. It may be built at various heights. In this project, raised spherical water tanks are manually developed using the limit state design approach and codes (IS 3370-2009(part I-IV) and IS 456-2000), with software design done using ETABS. Finally, compare the findings achieved manually and using software. At the conclusion of the project, it is noticed that the use of etabs results in a decrease in steel when compared to manual design.

Key Words: Elevated spherical water tank, limit state method, ETABS.

1. INTRODUCTION

A water tank is a structure which is used to store water. Nowadays, the need of water tank are increasing. The water from the tank can be used for many purpose like house work, irrigation, fire safety etc.. The shape and size of a water tank are decided as per the capacities of tank. The cost and materials used for the water tank are decided according to the construction. Mostly, spherical shape are more preferred for the water tank due to the uniform stress distribution. Design code used for the water tank design is IS 3370(Part I- IV).

spherical water tank are good for store large quantities of water and are economical. For elevated storage structure generally spherical water tank are commonly employed. Generally, spherical water tank with flat base are preferred which are more economical. The tank are generally supported on a ring beam and are supported on a number of columns. Normally, the diameter of ring beam is kept $\frac{3}{4}$ th of

diameter of water tank. The main forces acting on this water tank are uniformly distributed load which consist of self weight of slab and weight of water, upward ring beam load also is there. spherical water tank require less steel and concrete compare to rectangular water tank.

The main components for an elevated water tank are:

Top Dome

- Top Ring Beam
- Cylindrical Wall
- Base Slab
- Bottom Ring Beam

1.1 OBJECTIVES

The objectives of this study are listed below:

1. To compare the design of elevated spherical water tank done by Manually and ETABS software in reference to IS 3370 Part I-IV, IS 456- 2000.
2. To study how much amount of steel required for the water tank.
3. To study the comparison between manual design and software design.
4. To study the design steps of different element of elevated spherical water tank using limit state design method using IS codes (IS 3370 Part I-IV, IS 456- 2000).

2. MATERIALS AND METHODOLOGY

2.1 MATERIALS PROPERTIES

The grade of concrete is M30 and grade of steel is HYSD 415 for water tank construction.

2.2 METHODOLOGY

In this project work elevated spherical water tank is considered.

Initially manual design are done using limit state design method as per code IS 3370:2009(part I-IV) and IS 456:2000, from the manual design the dimensions and area of steel are obtained. The water tank model were done in ETABS software based on the dimensions from manual design . Analysis was carried out for various components of water tank using ETABS software. The analysis were done by applying all the loads acting on the water tank. After the analysis software design and detailing were done. Finally compare both the design results which are obtained from software and manually.

2.3 DESIGN OF spherical WATER TANK

The code used for the design are IS 1172(1993),IS:3370- 2009(part II-IV) and IS 456-2000.

In this study, for the design of water tank 4.5 lakh liter capacity is assumed.

Material

M30 - Grade of Concrete

Fe 415 - Grade of HYSD Reinforcement

PRELIMINARY DIMENSIONS

Storage volume for 450000 liters = 450 m³ Volume of water tank , $V = \pi \times r^2 \times h$ Assume height, $h = 4$ m

$$450 = \pi \times r^2 \times 4 \quad r = 6 \text{ m}$$

$$D = 12 \text{ m}$$

By putting the value of h and r $\text{Volume} = \pi \times 6^2 \times h$

$$= \pi \times 6^2 \times 4$$

$$= 450 \text{ m}^3 \text{ Free board} = 0.3 \text{ m}$$

Height of Staging from Ground = 10 m

PERMISSIBLE STRESSES

As per IS:3370 (part II) Table 1, Table 2 and Table 4 $\sigma_{cbc} = 10 \text{ N/mm}^2$

$$\sigma_{cc} = 8 \text{ N/mm}^2$$

$$\sigma_{st} = 130 \text{ N/mm}^2 \quad \sigma_{ct} = 1.5 \text{ N/mm}^2$$

DESIGN CONSTANTS

$$m = \frac{280}{3 \times \sigma_{cbc}} = 9.33$$

$$K = \frac{1}{1 + \frac{\sigma_{st}}{m \times \sigma_{cbc}}} = 0.42$$

$$j = 1 - \left(\frac{K}{3}\right) = 0.86$$

$$R = \frac{1}{2} \times K \times \sigma_{cbc} \times j = 1.81$$

2.4 DESIGN OF TOP DOME

(i) Meridional Force(T_1)

(ii) Hoop Tension(T_2)

Thickness of Dome (assuming) = 100 mm

Central rise of dome (h_1) = $\left(\frac{1}{5} \times \text{diameter}\right) = 2.4$ m Radius of curvature (R)

$$R^2 = (2r - \text{rise}) \text{ rise}$$

$$r = 8.7 \text{ m}$$

$$\text{Semi Central Angle } (\theta) = \sin^{-1} \left(\frac{\text{Radius of water tank}}{r} \right)$$

$$= 43.60^\circ$$

$$\cos \theta = 0.724$$

Calculation For Loads (for 1 m length of dome)

Length = 1 m

Dead load = Width x Thickness x Density

$$= 2.5 \text{ KN/m}^2$$

Live load = Width x Live load (assuming live load = 1.5 KN/m²)

= 1.5 KN/m² Total load (W) = 4 KN/m²

Ultimate load = 1.5 x 4 = 6 KN/m²

Stresses in Dome

$T_1 = (W \times R)/(1 + \cos\theta) = 30.27 \text{ KN/m}$

Meridional Stress = $T_1/(b \times t) = 0.302 \text{ N/mm}^2$

$0.302 \text{ N/mm}^2 < \sigma_{cc} = 8 \text{ N/mm}^2$

$T_2 = W \times R[\cos\theta - 1/(1 + \cos\theta)] = 8 \text{ KN/m}$ Hoop Stress = $T_2/(b \times t) = 0.08 \text{ N/mm}^2$

$0.08 \text{ N/mm}^2 < \sigma_{cc} = 8 \text{ N/mm}^2$

Stresses is within safe limits. As per IS:3370 (part 2) Table 2

Reinforcement in Dome

The stresses are within safe limit. However provide minimum reinforcement of 0.24% area in each direction

$A_{st} = 0.24\% \times b \times t = 240 \text{ mm}^2$

Using 8 mm ϕ bar, $A_{\phi} = 50 \text{ mm}^2$ Spacing = $1000 \times A_{\phi}/A_{st} = 208 \text{ mm}$

Hence provide 8 mm ϕ bars @ 200 mm c/c in both directions.

3. DESIGN OF TOP RING BEAM

It is designed for hoop tension $W = T_1 \cos\theta = 22 \text{ KN/m}$

Total hoop tension in beam = $W \times \frac{D}{2} = 132 \text{ KN}$

Area of Reinforcement

$A_{st} = \frac{\text{Hoop Tension}}{\sigma_{st}} = 1015 \text{ mm}^2$ Provide 12 mm ϕ @ 110 mm

To find out Dimensions of Ring Beam

$\sigma_{ct} = \frac{T}{A_g + (m-1)A_{st}}$ $A_g = b \times D$

Assume $b = 250 \text{ mm}$

$1.5 = \frac{132 \times 10^3}{250 \times D + (9.33-1) \times 1028}$

$\frac{132 \times 10^3}{250 \times D + 8563} < 1.5$

$132 \times 10^3 < 375 D + 12844$ $318 < D$

Consider $D = 400 \text{ mm}$

Size of beam = 250 mm x 400 mm Provide min. shear reinforcement 8 mm ϕ – 2 legged vertical stirrups From IS:456-2000, Page No – 48

$S_v = 362.96 \text{ mm}$

Spacing limit

(i) $0.75 \times D = 0.75 \times 400 = 300 \text{ mm}$

(ii) 300 mm

Adopt a ring beam of size 250 mm x 400 mm with 12 mm diameter as hoop reinforcement and 8 mm ϕ - 2 legged vertical stirrups @300 mm c/c.

3.1 DESIGN OF TANK WALL

Thickness of wall $T = 150 \text{ mm}$

$T = (30 H + 50) = 170 \text{ mm}$

Take the value of T. i.e, $T = 170 \text{ mm}$

Design of Tank Wall for Hoop Tension

$\frac{H^2}{DT} = 8$

As Per IS:3370 (part IV), Page No. 35, Table 9 Coefficient = 0.575

Hoop Tension = $\text{Coeff.} \times W \times H \times R$

= $0.575 \times 10 \times 4 \times 6 = 138 \text{ KN}$

i.e, Maximum Hoop Tension occurs at $0.6 H = 0.6 \times 4 = 2.4 \text{ m}$ from the top

Area of Steel for Tank Walls

$$A_{st(req)} = \frac{\text{Max.Hoop Tension}}{\text{Permissible Tensile Stress}} = 1061 \text{ mm}^2$$

Minimum Steel, As Per IS:3370, Part II, Page No. 5 $A_{st(min)} = 0.24\% \times \text{gross area} = 408 \text{ mm}^2$

Provide 12 mm diameter bar

$$\text{Spacing} = \frac{1000 \times A_{sv}}{A_{st}} = \frac{1000 \times 113}{1061} = 107 \text{ mm}$$

Provide 12 mm ϕ bar @ 100 mm c/c (As per IS:3370, Part II, Page No. 5)

Check for Tensile Stress in Concrete

$$A_{st(provided)} = 2 \times \frac{1000 \times 113}{100} = 2260 \text{ mm}^2$$

$$\sigma_{ct} = \frac{T}{b \times t + (m-1)A_{st}} = 0.73 \text{ N/mm}^2$$

Permissible tensile stress = 1.3 N/mm² (As per IS:3370, Part 2, Table 1)

i.e, Actual tensile stress < Permissible stress Design is safe

Design of Tank Wall for Bending Moment

As Per IS:3370, Part 4, Table 10 Coefficient = -0.0146

$$\text{Bending Moment} = \text{Coeff.} \times W \times H^3$$

$$= 0.0146 \times 10 \times 4^3 = 9.34 \text{ kNm}$$

Maximum Bending Moment = 9.34 kNm

Check for effective depth d

$$d(\text{required}) = \sqrt{\frac{M_{max}}{R \times b}} = \sqrt{\frac{9.34 \times 10^6}{1.81 \times 1000}} = 72 \text{ mm } d(\text{provided}) = 170 - 25 - 12/2 = 139 \text{ mm} > d(\text{required})$$

Hence, it is safe

Area of steel for Bending Moment

$$A_{st(required)} = \frac{\text{Max.B.M.}}{\sigma_{st} \times j \times d(\text{provided})} = 601 \text{ mm}^2 \text{ Provide 12 mm } \phi \text{ bars}$$

$$\text{Spacing} = \frac{1000 \times A_{sv}}{A_{st}} = \frac{1000 \times 113}{601} = 188 \text{ mm Provide 12 mm } \phi \text{ bar @ 170 mm c/c}$$

3.2 DESIGN OF BASE SLAB

Assuming thickness of base slab as 350 mm. Outer diameter = 12 + 0.34 = 12.34 m

$$\text{Load from Dome} = T_1 \sin \theta \times 2\pi \times \frac{D}{2} = 787 \text{ KN}$$

Load from Ring Beam = (.25X .40) x π x 12 x 25 = 94 KN Load of wall = 0.170 x (4-0.3) x π x 12.17 x 25 = 601.22 KN Total circumferential load on the periphery of slab = 1482 KN

$$\text{Ultimate load on periphery of slab} = 1482 \times 1.5 = 2223 \text{ KN Weight of water} = \left(\frac{\pi}{4} \times D^2 \times H \right) = 4523.90 \text{ KN}$$

Self weight of slab = 0.35 x 25 = 8.75 KN/m²

$$\text{Total weight of slab} = \left(\frac{\pi}{4} \times D^2 \right) \times sw = 989.60 \text{ KN Finishing load} = \left(\frac{\pi}{4} \times 12^2 \right) \times 0.6 = 67.86 \text{ KN}$$

Total load on slab = 5581.36 KN

Ultimate load on slab = 5581.36 x 1.5 = 8372 KN

Total upward force on Ring Beam = 2223 + 8372 = 10595 KN

For the design of slab two cases are considered.

(i) spherical slab simply supported and subjected to water pressure plus self weight of slab.

(ii) spherical slab simply supported and subjected to upward ring load.

Calculation of B.M. and S.F.

The radial and circumferential bending moments are calculated with the help of formulae given below.

B.M. due to U.D.L.

$$p = 8372 \text{ KN}$$

Now, to convert p to U.D.L.

$$\frac{8372}{(\frac{\pi}{4} \times 12^2)} = 74 \text{ KN/m}^2$$

$$a = \text{radius of slab} = \frac{12}{2} = 6 \text{ m}$$

Normally, the diameter of supporting circle is kept 3/4 times the diameter of the tank.

$$\text{Diameter of beam} = 9 \text{ m Radius of beam, } b = 4.5 \text{ m } (Mr)c = + \frac{3}{16} pa^2 ; (Mr)e = 0$$

$$Mr = \frac{3}{16} p (a^2 - r^2)$$

$$= \frac{3}{16} \times 74 (6^2 - r^2)$$

$$(M\theta)c = + \frac{3}{16} pa^2 ; (M\theta)e = + \frac{2}{16} pa^2 M\theta = + \frac{p}{16} (3a^2 - r^2)$$

$$= \frac{74}{16} \times (3(6)^2 - r^2)$$

The values of $M\theta$ and Mr at various locations are tabulated below

r (m)	0	2.25	4.5	6
Mr (KNm)	499.5	429.26	218.53	0
Mθ (KNm)	499.5	476.19	405.84	333

B.M. due to upward load $W = 10595 \text{ KN}$ For $r \leq b$

$$Mr = (Mr)b = M\theta = (M\theta)0 = - \frac{w}{8\pi} [2 \log \left(\frac{a}{b} \right) + 1 - \left(\frac{b}{a} \right)^2]$$

For $r > b$

$$Mr = - \frac{w}{8\pi} [2 \log \left(\frac{a}{r} \right) - \left(\frac{b}{a} \right)^2 + \left(\frac{b}{r} \right)^2]$$

$$M\theta = - \frac{w}{8\pi} [2 \log \left(\frac{a}{r} \right) - \left(\frac{b}{r} \right)^2 + 2 - \left(\frac{b}{a} \right)^2]$$

The values of $M\theta$ and Mr at various locations are tabulated below

r (m)	0	2.25	4.5	6
Mr (KNm)	-289.77	-289.77	-289.77	0
Mθ (KNm)	-289.77	-289.77	-289.77	-369

Net Moments:

The net moments will be the algebraic sum of the two, and are tabulated below

r (m)	0	2.25	4.5	6
Mr (KNm)	209.73	139.5	-71.24	0
Mθ (KNm)	209.73	186.42	116.07	-36

The maximum shear force

$$F = \frac{pb}{2} - \frac{W}{2\pi b} = \frac{74 \times 4.5}{2} - \frac{10595}{2 \times \pi \times 4.5} = -208.22 \text{ KN}$$

DESIGN OF SLAB

The slab is to be designed for a maximum B.M. of 209.73 KNm.

$$\text{From B.M. point of view, } d = \frac{\sqrt{Mu_{max}}}{R \times b} = 340 \text{ mm Let us keep total thickness} = 380 \text{ mm}$$

Using 20 mm ϕ bars,

$$\text{Provide } d = 380 - 25 + 10 = 365 \text{ mm Effective depth } d = 365 \text{ mm}$$

$$\text{Area of steel} = \frac{0.5 f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 Mu_{max}}{f_{ck} b d^2}} \right] b d$$

$$= 1702.06 \text{ mm}^2$$

$$\text{Using 20 mm diameter bars, } A\phi = 314 \text{ mm}^2 \text{ Spacing} = \frac{1000 \times 314}{1702.6} = 184 \text{ mm}$$

Provide 20 mm ϕ @ 180 mm c/c

At Ring Beam (Mr)

$$\text{Area of steel} = \frac{0.5 f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 M_{u,max}}{f_{ck} b d^2}} \right] b d$$

$$= 552 \text{ mm}^2$$

$$\text{Using 12 mm diameter bars, } A_{\phi} = 113 \text{ mm}^2 \text{ Spacing} = \frac{1000 \times 113}{552.42} = 204 \text{ mm}$$

Provide 12 mm ϕ @ 200 mm c/c

At Ring Beam (M0)

$$\text{Area of steel} = \frac{0.5 f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 M_{u,max}}{f_{ck} b d^2}} \right] b d$$

$$= 913 \text{ mm}^2$$

$$\text{Using 16 mm diameter bars, } A_{\phi} = 201 \text{ mm}^2 \text{ Spacing} = \frac{1000 \times 201}{912.78} = 220 \text{ mm}$$

Provide 16 mm ϕ @ 210 mm c/c

$$\text{Provide min. steel at other remaining surface } A_{st(min)} = \frac{0.24}{100} \times 1000 \times 380 = 912 \text{ mm}^2 \text{ Spacing} = \frac{1000 \times 113}{912} = 123 \text{ mm}$$

Provide 12 mm ϕ @ 115 c/c

DESIGN OF BOTTOM SPHERICAL BEAM

The tank is supported on a spherical beam which in turn is supported on eight equally spaced columns. The diameter of supporting circle, upto the centre of the beam = 9 m. The total load W on the beam = 10595 KN.

For the design of Bottom Ring Beam

$$\text{Super - imposed load on beam} = \frac{10595}{\pi \times 9} = 374.72 \text{ KN/m Assuming the beam to have a section of } 1000 \text{ mm} \times 500 \text{ mm,}$$

$$\text{Self Weight of Beam} = 0.1 \times 0.5 \times 25 = 12.5 \text{ KN/m}$$

$$\text{Total Weight, } W = 374.72 + 12.5 = 387.5 \text{ KN/m For } \theta,$$

$$2\theta = (360^\circ)/n \quad n = 8$$

$$2\theta = 45^\circ = \pi/4$$

$$\theta = 22.5^\circ = \frac{\pi}{8}$$

$$C1 = 0.066, C2 = 0.030, C3 = 0.005, \phi_m = 9 \frac{1}{2}$$

$$\text{Radius of beam} = \frac{9}{2} = 4.5 \text{ m}$$

$$WR^2.2\theta = 387.5 \times 4.5^2 \times (\pi/4) = 6163 \text{ KNm}$$

$$\text{Max. Negative Bending Moment at Support, } M_n = C1 \times WR^2(2\theta) = 406.75 \text{ KNm}$$

$$\text{Max. Positive Bending Moment at mid-span, } M_p = C2 \times WR^2(2\theta) = 184.89 \text{ KNm}$$

$$\text{Max. Torsional Moment at an angle of } 9.5^\circ \text{ from support, } T = C3 \times WR^2(2\theta) = 30.81 \text{ KNm}$$

$$\text{Max. Shear force at support, } V = \frac{w \times R \times 2\theta}{2} = 684.76 \text{ KN Shear force at section of maximum torsional moment } (\phi_m = 9.5^\circ = 0.1658 \text{ radians}) \text{ is given by :}$$

$$V_T = wR (\theta - \phi_m) = 387.5 \times 4.5 \left(\frac{\pi}{8} - 0.1658 \right) = 395.65 \text{ KN}$$

Design of support section

$$M_{max} = 406.75 \text{ KN, } D = 1000 \text{ mm, } V = 684.76 \text{ KN}$$

$$\text{Using 20 mm } \phi \text{ bars and a clear cover 35 mm, } d = 1000 - 10 - 35 = 955 \text{ mm}$$

Min. depth required:

$$M_{u,lim} = 0.36 \times \frac{X_{u,max}}{d} \left(1 - 0.42 \frac{X_{u,max}}{d} \right) b d^2 f_{ck} d = 443 \text{ mm}$$

$$\text{Hence, provide } d_{eff} = 955 \text{ mm}$$

Area of Steel required

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{A_{st} f_y}{b d f_{ck}} \right) A_{st} = 1223 \text{ mm}^2$$

$$A_{stmin} = \frac{0.85 \times b d}{f_y}$$

$$A_{stmin} = 978 \text{ mm}^2$$

$$\text{No. of bars} = \frac{A_{st}}{A_{\phi}} = \frac{1223}{\frac{\pi}{4} \times (20)^2} = 4 \text{ Nos. Provide 4 bars of 20 mm } \phi \text{ reinforcement } A_{stprovided} = 1256 \text{ mm}^2$$

$$\text{Nominal shear strength } (\tau_v) \tau_v = \frac{V_u}{b d}$$

$$\tau_v = 1.4 \text{ N/mm}^2$$

$$\text{Compressive shear strength } (\tau_c)$$

$$\text{Percentage of reinforcement } (p\%) = 100 \frac{A_{st}}{b d} = 0.26 \text{ Thus, from table 19 IS 456:2000}$$

$$\tau_c = 0.3752 \text{ N/mm}^2$$

$$\tau_c < \tau_v$$

$$\text{Thus, shear reinforcement is required } V_{us} = V_u - \tau_c b d$$

$$V_{us} = 684.76 - 0.3752 \times 500 \times 955 \quad V_{us} = 505.76 \text{ KN}$$

$$V_{us} = \frac{0.87 \times f_y A_{sv} d}{S_v}$$

$$\text{Using 10 mm } \phi \text{ stirrups (2 - legged) } A_{sv} = 2 \times \frac{\pi}{4} \times (10)^2 = 157 \text{ mm}^2$$

$$S_v = \frac{0.87 \times 415 \times 157 \times 955}{505.76 \times 10^3} = 107.03 \text{ mm} \approx 107 \text{ mm Provide 10 mm } \phi \text{ 2 - legged stirrups @ 105 mm c/c}$$

$$\text{Design of Mid- Span Section}$$

$$M = 184.89 \text{ KNm}$$

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{A_{st} f_y}{b d f_{ck}} \right) \quad A_{st} = 544 \text{ mm}^2$$

$$\text{But min area of steel is } 978 \text{ mm}^2$$

$$\text{Hence, adopt } A_{st} = 978 \text{ mm}^2$$

$$\text{Using 16 mm } \phi \text{ bars } (A_{\phi} = 201 \text{ mm}^2) \text{ No. of bars} = \frac{978}{201} = 5 \text{ Nos.}$$

$$\text{Provide 6 bars of 16 mm } \phi \text{ reinforcement}$$

Design of section subjected to Max. Torsional and Shear

$$\text{Equivalent Bending Moment } M_{el} = M_u + M_t$$

$$M_u = 0$$

$$M_t = T_u \frac{\left(1 + \frac{D}{b} \right)}{1.7}$$

$$M_t = 30.81 \times \frac{\left(1 + \frac{1000}{500} \right)}{1.7} \quad M_t = 54.37 \text{ KNm}$$

$$M_{el} = 54.37 \text{ KNm}$$

$$\text{Area of Reinforcement}$$

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{A_{st} f_y}{b d f_{ck}} \right) \quad A_{st} = 158 \text{ mm}^2$$

$$\text{But } A_{stmin} = 978 \text{ mm}^2$$

$$\text{Hence, adopt } A_{st} = 978 \text{ mm}^2$$

$$\text{Using 20 mm } \phi \text{ bars } (A_{\phi} = 314 \text{ mm}^2) \text{ No. of bars} = \frac{978}{314} = 3 \text{ Nos.}$$

$$\text{Provide 3 bars of 20 mm } \phi \text{ reinforcement}$$

Transverse reinforcement Shear reinforcement Equivalent Shear

$$V_e = V_u + 1.6 \frac{T_u}{b}$$

$$V_e = 395 + 1.6 \times \frac{30.81}{0.5} \quad V_e = 493.6 \text{ KN}$$

$$\tau_v = \frac{V_u}{b d}$$

$$\tau_v = 1 \text{ N/mm}^2$$

$$\text{Percentage of reinforcement} = 100 \frac{A_{st}}{b d} = 0.205 \text{ Thus, from table 19 IS 456:2000}$$

$$\tau_c = 0.334 \text{ N/mm}^2$$

$$\tau_v > \tau_c$$

Shear reinforcement is required

Using 10 mm ϕ 2 – legged stirrups ($A_{st} = 157 \text{ mm}^2$) $b_1 = 500 - 35 - 35 = 430 \text{ mm}$

$$d_1 = 1000 - 35 - 35 = 930 \text{ mm}$$

$$A_{sv} = \frac{T_u S_v}{b_1 d_1 (0.87 f_y)} + \frac{V_u S_v}{2.5 d_1 (0.87 f_y)}$$

$$157 = \left[\frac{30.81 \times 10^6}{430 \times 930 \times (0.87 \times 415)} + \frac{395 \times 10^3}{2.5 \times 930 \times (0.87 \times 415)} \right] S_v$$

$$S_v = 229 \text{ mm}$$
 Check for spacing

$$(i) x_1 = 430 \text{ mm}$$

$$(ii) \frac{x_1 + y_1}{4} = \frac{430 + 930}{4} = 340 \text{ mm}$$

$$(iii) 300 \text{ mm}$$

Provide 10 mm ϕ 2 – legged stirrups @ 220 mm c/c

Side face reinforcement (As per IS 456 – 2000)

$$A_s = \frac{0.10}{100} \times 500 \times 955 = 477 \text{ mm}^2$$

$$12 \text{ mm } \phi \text{ bars having , } A_{\phi} = 113 \text{ mm}^2 . \text{ No. of bars } = \frac{477}{113} = 4.2$$

Provide 3 - 12 ϕ bars on each vertical face

4. MANUAL DESIGN RESULT DETAILS

Table – 1: Manual Design Result

SL. NO.	COMPONENTS OF WATER TANK	MANUAL DESIGN
		$A_{st} \text{ in mm}^2$ (Required)
1	Top Dome	240 mm ²
2	Top Ring Beam	1015 mm ²
3	Tank Wall	
a	Hoop Reinforcement	1061 mm ²
b	Bending Reinforcement	601 mm ²
4	Base Slab	
a	Reinforcement For Max. Bending Moment	1702 mm ²
b	Reinforcement Of Radial Moment At Ring Beam	552 mm ²
c	Reinforcement Of Circumferential Moment At Ring Beam	913 mm ²
5	Bottom Ring Beam	
a	Support Section	1223 mm ²
b	Mid-Span Section	978 mm ²
c	Maximum Torsion	978 mm ²
d	Transverse Reinforcement	685 mm ²

MODEL DETAILS

For the design of water tank we have to create a model first. The modeling was done in ETABS software. Once the modeling was completed with desired material and section properties the model were subjected to analysis based on the load acting on the tank and after that design were done. The project work is focused on the Comparative Study of spherical overhead water tanks by manually and software. In both cases the dimensions of tank are same. The location considered for this project is Kannur, Kerala.

Table – 2: Water Tank Model Details

Sl.No	Description	spherical Elevated Water Tank
1	Diameter of Column	800 mm
2	No. of Column	8
3	Bottom Ring Beam	500 mm x 1000 mm
4	Bracing	800 mm x 500 mm
5	Height of Staging (m)	10 m
6	Thickness of Slab	380 mm
7	Diameter of Tank (m)	12 m
8	Height of Tank Wall (m)	4 m
9	Thickness of Tank Wall	170 mm
10	Top Ring Beam	250 mm x 400 mm
11	Roof Slab Thickness (Dome Shape)	100 mm
12	Center Height of Dome (m)	2.4 m
13	Type of Soil	Moderate Soil
14	Unit Weights	Concrete = 25 KN/m ³
15	Material	M30 Grade Concrete and Fe415

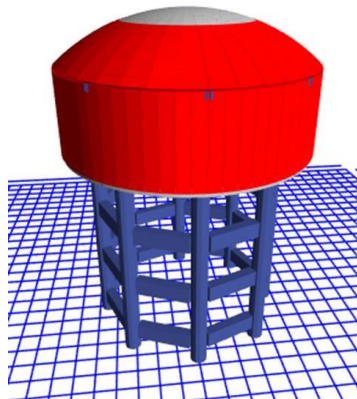


Fig – 1: 3 D Rendered Model

4.1 LOADS ACTING ON THE WATER TANK

Dead load:

Dead load means the load due to the materials of the construction. i.e, unit weight of material x dimension or diameter of a section. Unit weight of concrete is 25 Kn/m³.

Live load:

Load exerted by the living beings. In water tank load of water also consider as live load.

Wind load:

Wind load details as per IS: 875 (part I-III),for the design

Basic wind speed (Vb) = 39m/sec Terrain factor = 3

windward coefficient = 0.8 Leeward coefficient = 0.5 risk coefficient k1= 1.06 topography k3=1 importance factor = 1

Earth quake load:

Earth quake load as per IS:1893(part I-II), for the design

Seismic Zone = III Zone factor = 0.16 Importance factor =1.5

Response reduction factor =1.8

4.3 STRESS DIAGRAM AFTER ANALYSIS

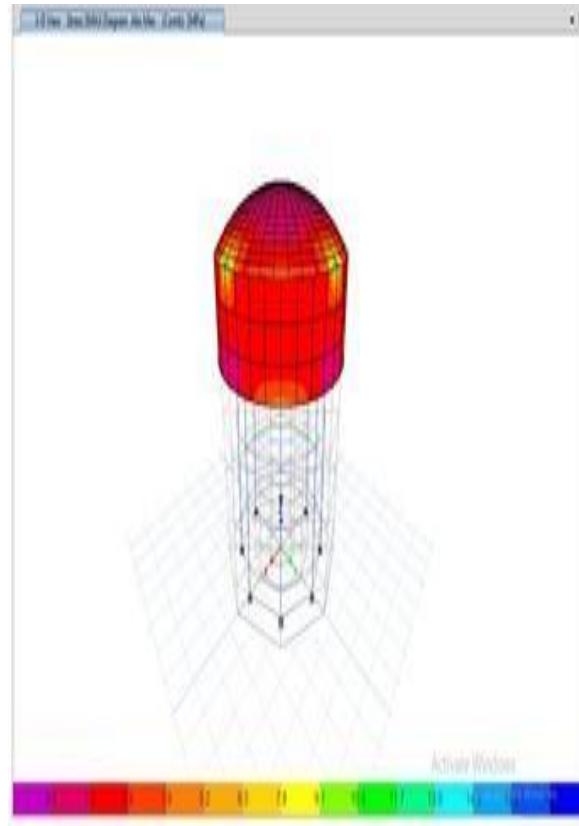


Fig-2: Absolute Maximum Stress Diagram

Maximum absolute stress is 15.15 N/mm².

4.4 SOFTWARE DESIGN RESULT DETAILS

Table-3: Software Design Result

SL. NO.	COMPONENTS OF WATER TANK	SOFTWARE DESIGN
		Ast in mm ² (Required)
1	Top Dome	200 mm ²
2	Top Ring Beam	983 mm ²
3	Tank Wall	
a	Hoop Reinforcement	942 mm ²
b	Bending Reinforcement	495 mm ²
4	Base Slab	
a	Reinforcement For Max. Bending Moment	1653 mm ²
b	Reinforcement Of Radial Moment At Ring Beam	526 mm ²
c	Reinforcement Of Circumferential Moment At Ring Beam	874 mm ²
5	Bottom Ring Beam	
a	Support Section	1163 mm ²
b	Mid-Span Section	935 mm ²
c	Maximum Torsion	935 mm ²
d	Transverse Reinforcement	628 mm ²

5. RESULT AND DISCUSSION

In this study, elevated spherical water tank was first designed by manually using limit state design method as per IS 456- 2000 and IS 3370-2009(part I-IV) and then compare that results with ETABS software design results. Comparative result of elevated spherical water tank

Table-4: Comparison Result

SL. NO.	COMPONENTS OF WATER TANK	MANUAL DESIGN	SOFTWARE DESIGN
		Ast in mm ² (Required)	Ast in mm ² (Required)
1	Top Dome	240 mm ²	200 mm ²
2	Top Ring Beam	1015 mm ²	983 mm ²
3	Tank Wall		
a	Hoop Reinforcement	1061 mm ²	942 mm ²
b	Bending Reinforcement	601 mm ²	495 mm ²
4	Base Slab		
a	Reinforcement For Max. Bending Moment	1702 mm ²	1653 mm ²
b	Reinforcement Of Radial Moment At Ring Beam	552 mm ²	526 mm ²
c	Reinforcement Of Circumferential Moment At Ring Beam	913 mm ²	874 mm ²
5	Bottom Ring Beam		
a	Support Section	1223 mm ²	1163 mm ²
b	Mid-Span Section	978 mm ²	935 mm ²
c	Maximum Torsion	978 mm ²	935 mm ²
d	Transverse Reinforcement	685 mm ²	628 mm ²

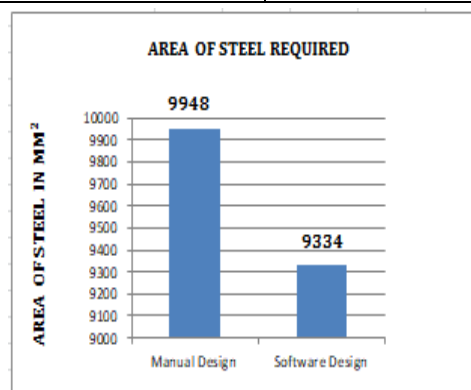


Chart-1: Steel Distribution

6. CONCLUSIONS

In this project a study is made to compare the design of elevated spherical water tank by manual method and software method. To know about the area of steel required for the water tank.

From the study it is finally conclude that.

- The amount of steel required for the whole structure is less for software design compare to manual design.
- The total steel required from software design is 9334 mm² and manual design is 9948 mm².
- While comparing with manual design software design saves 10% of steel in whole structure.
- Manual design method require more time and complicated. Whereas the design done in etabs software require less time.

7. REFERENCES

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