

# Design and Analysis of Circular Overhead Intze Water Tank by StaadPro V8I SS6 Software

Shahid Nazir<sup>1</sup>, and Ashish Kumar<sup>2</sup>

<sup>1</sup>M. Tech Student, Department Civil Engineering, RIMT University Mandi Gobindgarh, Punjab India

<sup>2</sup>Assistant Professor, Department Civil Engineering, RIMT University, Mandi Gobindgarh, Punjab India

Correspondence should be addressed to Shahid Nazir; [Shahidnazirsn211@gmail.com](mailto:Shahidnazirsn211@gmail.com)

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**ABSTRACT-** Water is the most essential component of all life on Earth. It accounts for around 71.4 percent of the earth's surface. It is the most prevalent chemical in the human body. In a city of 20,000 inhabitants, the average daily water use is 200 litres. To fulfil the public's enormous demand, water must be stored and supplied. The demand for water does not remain consistent throughout the day. It differs from one hour to the next. We must save water in order to provide a consistent volume of water. As a result, a water tank must be built to supply the public's water needs. Water, liquid petroleum, petroleum products, and similar liquids are stored in storage reservoirs and overhead tanks. Regardless of the chemical composition of the substance, the force analysis of reservoirs or tanks is roughly the same. To prevent leaking, all tanks are built as crack-free constructions.

Water is also essential in the agricultural and industrial sectors. Water demand is a critical problem in water supply planning. To address this issue, current water tank designs must be updated. The most effective storage facility utilised for home or even industrial purposes is an above water tank.

**KEYWORDS-** Hydrostatic pressure, Intze, Meridional stress, Hoop stress, analysis, IS code design criterion

## I. INTRODUCTION

"Every drop of water that will ever exist is right now." As a result, it is an alarming situation for retaining water in the current scenario when it is a scarce commodity. Water retention structures, often known as water storage tanks, are an essential component of any distribution system[1]. During periods of low demand, water is pumped into the storage tank, and during periods of high demand, water is pushed out of the storage tank and into the distribution system[2]. When especially considering constructions that store liquids, the most important factor to consider is the imperviousness of concrete. This concrete should be abundant in cement, extremely highly graded, and minutely compacted in order to achieve high tensile strength and low porosity[3].

In general, the minimum grade of concrete utilised in the building of these structures is M25, and the cement amount ranges from 330 to 530 kg/m<sup>3</sup>.

The imperviousness of concrete is critical in the construction of concrete structures for the storage of water and other

liquids. The permeability of any uniformly and thoroughly compacted concrete with given mix proportions is primarily determined by the water cement ratio. The permeability increases as the water cement ratio increases[4]. A drop in water cement ratio will thus be beneficial to minimise permeability, but a very low water cement ratio may produce compaction issues and may even be dangerous.

The design of a liquid-retaining structure must be centred on avoiding breaking in the concrete due to its tensile strength. Cracks can be avoided by avoiding the use of heavy timber shuttering, which allows heat of hydration to escape easily from the concrete mass[5]. The likelihood of cracking can also be reduced by loosening the structure's constraints on free expansion and contraction. The major design feature of conventional structures is structural stability and load resistance[6]. Structures meant to store liquids, on the other hand, must be resistant to perforation and leaking, as well as structural stability, resistance, and adequate strength against deformation and cracking. Cracking is caused by a lack of quality control, resulting in concrete leakage and degradation. The primary cause of collapse of these constructions is thus unlawful material, mix, placement, compaction, leakage, formwork, and temperature [7].

Concerning cracking in these structures, it may occur for the reasons listed below:

- Exposed external loads cause direct or flexural tension in concrete.
- Solar radiation causes temperature gradients.
- Liquid containment at temperatures above ambient may result in cracking.
- Effects of temperature and moisture.
- Dimensional changes caused by temperature and moisture fluctuations are resisted either inside or externally.
- Cracking may occur if the temperature rises for a day or longer and then falls back to ambient during the development of heat due to cement hydration.

By keeping the concrete moist and filling the tank as soon as possible, the danger of breaking due to shrinkage and temperature difference may be reduced. When examining the design of any structure, the primary goal should be to ensure that its end-of-life is avoided. This can happen as a result of

one of two things: first, a loss of load-bearing capability, or second, an increase in permeability of the concrete, allowing an undesirable flow of water through the structure.

## II. OBJECTIVES

- To conduct research on the analysis and design of water tanks with Manual Check and StaadPro Designing.
- To conduct research on the recommendations for the design of liquid-retaining structures in accordance with the IS code.
- To investigate the various forces at work on a water tank. Understanding the most critical variables in the design of a water tank.
- To learn about the design philosophy for the safe and cost-effective design of a water tank.
- To eliminate tiresome calculations, construct programmes for the design of water tanks with flexible and stiff bases, as well as subterranean tanks.
- Preparing an affordable and safe water tank design, giving suitable steel reinforcement in concrete, and researching its safety in accordance with various codes.

## III. METHODOLOGY

The stages of this work are:

- Creation Of Top Spherical Dome
- Creation Of Top Ring Beam
- Creation Of Cylindrical Walls
- Creation Of Middle Ring Beam
- Creation Of Bottom Ring Beam
- Creation Of Conical Dome
- Creation Of Bottom Spherical Dome
- Creation Of Supporting Columns For Tank
- Creation Of Supporting Braces
- Assigning Material Property To Structural Members
- Load Cases And Definitions For Members
- Design & Material
- Result Of Analysis
- Future Scope & Conclusion

## IV. STRUCTURAL ELEMENTS OF INTZE TANK

The structural parts of the intze tank are as follows:

- Top spherical dome.
- Top ring beam B1-Girder.
- Circular side wall d. Bottom ring beam B2-Girder.
- Spherical bottom dome.
- B3 bottom ring beam.
- Staging: - Bracings, Columns, and Footings.

For such tanks, the allowable stress specified in IS 3370 is as follows:

Stresses of various kinds: Allowable stress in  $N/mm^2$  High yielding power Plain bars conforming to deformed bars in accordance with IS 432-1966 Grade-I. Is it 1786-1966, or is

it 1139-1966? Tensile tension in members is subjected to no table of contents items discovered by direct load.

The direct tensile stress in concrete is  $1.1 N/mm^2$ ,  $1.2 N/mm^2$ ,  $1.32 N/mm^2$ ,  $1.5 N/mm^2$ ,  $1.6 N/mm^2$ , and  $1.7 N/mm^2$  for M15, M20, MM25, M30, M35, and M40, respectively, with the value in tension owing to bending being  $1.5 N/mm^2$ ,  $1.7 N/mm^2$ ,  $1.82 N/mm^2$ ,  $2.0 N/mm^2$ ,  $2.2 N/mm^2$  and  $2.4 N/mm^2$ .

When it is anticipated that steel and concrete will work together to check the tensile stress in concrete to avoid fractures, the tensile stress in steel will be regulated by the criteria that the stress specified above not be exceeded. The modular ratio multiplied by the appropriate tensile stress in concrete will be used to calculate the tensile stress in steel.

## V. METHODS OF POPULATION FORECAST

- Arithmetic Progression Method

$$\text{Population } (P_n) = P_o + nX = 4200 \dots\dots\dots n=1 \text{ Decade}$$

- Geometric Progression Method

$$\text{Population } (P_n) = P_o (1 + r)^n = 4745$$

- Incremental Increase Method

$$\text{Population } (P_n) = P_o + nX + \frac{n(n+1)}{2} Y = 3600$$

Maximum daily demand =  $1.8 \times$  average daily demand  
Maximum hourly demand of maximum day i.e., Peak demand

$$\begin{aligned} &= 1.5 \times \text{average hourly demand} \\ &= 1.5 \times \text{Maximum daily demand}/24 \\ &= 1.5 \times (1.8 \times \text{average daily demand})/24 \\ &= 2.7 \times \text{average daily demand}/24 \\ &= 2.7 \times \text{annual average hourly demand} \end{aligned}$$

Considering geometric increase method  $P_{2030} = 4745 = 5000$   
Therefore, design population of 5000 Assuming per capita demand 165-lpcd Capacity required =  $165 \times 5000$  lpcd = 825000 - lpcd in one day = 825000 - lit = 825 m<sup>3</sup>  
Design volume or capacity = 825000 - lit = 825 m<sup>3</sup>  
Table (1) shows the Population Forecast of Village

**VI. POPULATION FORECAST**

Table 1: for Population Forecast of Village

Year	Houses	Population	Increment(Y)	$P_n = P + nC$	Geometric Increase Growth Rate	$P_n = P(1 + Ig/100)^n$
1970	100	600	$P_2 - P_1$		$P/P_2 - P_1$	
1980	150	1000	400		0.67	
1990	300	1800	800		0.80	
2000	450	3000	1200		0.67	
2010	500	3200	200		0.07	
2020	600	3600	400		0.13	
		Avg. Inc C.=	600		IG Geometric Mean=	31.83
2030		Total(Y) =	3000	4200		4745.88

**VII. STRUCTURAL DESIGNING**

Table 2 shows the Designing of water tank by M30-HYSD Bars

Table 2: Designing by M30-HYSD Bars

S. No	Structural Element	Dimensions	Area of Steel Required	Reinforcement Details	Spacing
01	Top Spherical Dome	$D = 12m, R_1 = 10m, H_1 = 2m$	$240mm^2$	8mm	200mm
02	Top Ring Beam	230 x 300 mm	$500mm^2 @ 2L-8mm$	2#10mm	105mm
03	Top Cylindrical Walls	$H = 6m, T_w = 250mm$	461,923,1384,1846,2322, 2769 $mm^2$ for 1,2,3,4,5,6 m respectively	8,10,10,12,16,16mm respectively	100mm
04	Middle Ring Beam	300 x 450mm	$255mm^2$	4#10mm	160mm
05	Bottom Ring Beam	300 x 650mm	$379mm^2 @ 2L-8mm$	5#10mm	125mm
06	Bottom Conical Dome	$H_2 = 2.5m$	$550mm^2$	16mm	100mm
07	Bottom Spherical Dome	$H_3 = 1.5m, D_3 = 7m, R_3 = 4.83m$	$600 mm^2$	10mm	604mm
08	Supporting Columns	700 x 750mm	$1369 mm^2$	25mm	250mm
09	Supporting Braces	500 x 700mm	...	10mm	150mm

**VIII. ASSIGNING PROPERTY TO BEAMS, COLUMNS & PLATES**

In Modelling Mode Click on General then Click Property option a dialog box “Properties Whole-Structure” Click on Define then Choose Rectangle Section from Dialog box “Property” and Fill YD and ZD as 0.30 x 0.23, 0.45 x 0.30, 0.30 x 0.70, 0.75 x 0.70, 0.70 x 0.50 m`s and click on Add for Top Ring Beam, Middle Ring Beam, Bottom Ring Beam, Bracing Beams and Vertical supporting Columns

respectively. After Defining Structural Members Click on Thickness and in the “Plate Element Thickness” Dialog box input thickness as 100mm, 225mm, 250mm, 500mm and click on Add for Top Spherical Dome, Cylindrical Wall, Bottom Conical Dome, Bottom Spherical Dome respectively. Select All These Members one by one and Assign these Properties to respective members by Assign to Selected Beams option then also Select one by one by Plates Cursor

all Structural Plate Elements and Assign respective Thickness to them by Choosing “Assign to selected Plates”.

## IX. LOAD DEFINITIONS

### A. Seismic Definition

For defining loads and definitions move towards Modelling Mode and Click on Loads and Definitions a dialog box will Pop-up showing “Definitions, Load Cases Details and Load Envelopes” first of all we need to define loads so click on Definitions +Sign to open Different definitions and then click first Seismic Definitions which is necessary to define first of all definitions click on Add and a Dialog box will appear “Seismic Parameters” from Type Select “Indian: IS 1893-2000/2005”, click on Generate and choose Zone: Zone IV, Response Reduction: SMRF, Importance factor: Important buildings, Rock/Soil type: Medium Soil, structure type: RC Frame building, Damping Ratio: 0.05% click on Generate and click on Add. After that it will show Self-Weight, click to Add and also Add Member Weight and Element Weight as Uniform 7.625 KN/m<sup>2</sup> and 33 KN/m<sup>2</sup> respectively. Now Apply this Self Weight, Member Weight and Element Weight by Assign to View option, Selecting Members of Tank and Assign to Selected Beams and then Selecting Plates and Assigning by Assign to Selected Plates.

### B. Wind Definition

Now, again click on Wind Definitions and Add after that a Dialog box will appear showing Intensity and Exposure select Intensity, in Intensity you can manually input Intensity magnitude as per Height of the building or click on Calculate as per ASCE-7 and A Dialog box will pop-up showing 3 options as common, Main Building Data and Building Design Pressure here we have chosen ASCE-7: 2010, Building Classification Category: **Category I**, Basic Wind Speed: 3km/hr, Exposure Category: B, Structure type: Chimney-Tank and Click on OK then Click to Add as we have done with this step a dialog box will appear showing Exposure and type Exposure:1 and click to Add it .

A necessary step to follow here for Error free Analysis is that you have to Assign This Exposure and Wind Definition After Assigning Load Cases and Details. Analysis shows Errors that Wind Loads Are Added After Assigning all Loads to structure.

### C. Seismic Loads

After defining Loads, we need to add Loads and their Details, for this purpose click Load Cases and Details to Add as it is added a dialog box will pop-up showing Load cases with options as Primary, Load Generation, Define Combinations and Auto Load Combinations by default Primary is selected and choose Loading Type: Seismic and Rename as Seismic EQ-X click to Add again Add by Renaming as Seismic EQ-Z.

Now, Click on Seismic EQ-X and click to Add, a Dialog box will appear showing “Add New: Load Items” by Default Self Weight Load is showing from Self Weight Load Item; click Seismic Loads and Factor and Direction Window will pop-up now choose Direction: X Direction with Factor: 1 and click to Add. Again, repeat the same steps to click Seismic

and Factor and the Direction Window will pop-up. Now choose Direction: X Direction with Factor: -1 and click to Add.

Similarly Click on Seismic EQ-Z and click to Add, a Dialog box will appear showing “Add New: Load Items” by Default Self Weight Load is showing from Self Weight Load Item; click Seismic and Factor and Direction Window will pop-up now choose Direction: Z Direction with Factor: 1 and click to Add. Again, repeat the same steps to click Seismic and Factor and the Direction Window will pop-up. Now choose Direction: Z Direction with Factor: -1 and click to Add. To Assign this Created Load detail Click Seismic EQ-X then Select Assign to View, then Click OK to Confirm assigning. Again, Click Seismic EQ-Z then Select Assign to View then Click OK to Confirm assigning.

### D. Wind Loads

The definition of Loads needs to add Loads and their Details; for this purpose, click Load Cases and Details to Add similarly. As it is added a dialog box will pop-up showing Load cases with options as Primary, Load Generation, Define Combinations and Auto Load Combinations by default Primary is selected and choose Loading Type: Wind and Rename as Wind WN-X click to Add again Add by Renaming as Wind WN-Z.

Now, Click on Wind WN-X and click to Add, a Dialog box will appear showing “Add New: Load Items” by Default Self Weight Load is showing from Self Weight Load Item; click Wind Load and Wind Load Window will pop-up now choose Exposed Surface and Direction: X (Windward Face) with Factor: 1 and Define X/Y/Z Ranges and click to Add. Again, repeat the same steps to click Wind Load and Wind Load Window will pop-up. Choose Exposed Surface and Direction: -X (Leeward/Sidewall Face) with Factor: 1 and Define X/Y/Z Ranges and click to Add.

Similarly Click on Wind WN-Z and click to Add, a Dialog box will appear showing “Add New: Load Items” by Default Self Weight Load is showing from Self Weight Load Item; click Wind Load and Wind Load Window will pop-up now choose Exposed Surface and Direction: Z (Windward Face) with Factor: 1 and Define X/Y/Z Ranges and click to Add. Again, repeat the same steps to click Wind Load and Wind Load Window will pop-up. Choose Exposed Surface and Direction: -Z (Leeward/Sidewall Face) with Factor: 1 and Define X/Y/Z Ranges and click to Add.

To Assign this Created Load detail Click Wind WN-X then Select Assign to View, then Click OK to Confirm assigning. Again, Click Wind WN-Z then Select Assign to View then Click OK to Confirm assigning.

### E. Dead Loads

In the Primary Window, choose Loading Type: Dead and Rename as DL, click to Add.

Now, Click on DL and click to Add, a Dialog box will appear showing “Add New: Load Items” by Default Self Weight Load is showing from the Self Weight Load Item choose Direction: Y and Factor: -1 for applying Self Weight Vertically Downwards direction.

To Assign this Created Load detail Click Self Weight Then Select Assign to View then Click OK to Confirm assigning.



### F. Fluid Loads

For defining Fluid Loads, we need to add Loads and their Details, for this purpose click Load Cases and Details to Add as it is added a dialog box will pop-up showing Load cases with options as Primary, Load Generation, Define Combinations and Auto Load Combinations by default Primary is selected and choose Loading Type: Fluids and Rename as Water Pressure.

Now, Click on Wind WN-X and click to Add, a Dialog box will appear showing "Add New: Load Items" by Default Self Weight Load is showing from Self Weight Load Item; click Plate Loads and Pressure on Full Plate is showing by default Click Hydrostatic a Window will pop-up naming Hydrostatic now first click Select Plates and Dialog box naming "Select Items" will pop-up, choose plates Cursor and Select plates one by one according to Loads acting on them by water Pressure and Click Done. Now, Force input will be Activated for manual input values and input your values as  $W1 = 17\text{kN/m}^2$  as minimum and  $W2 = 60\text{ KN/m}^2$  as maximum choose Direction of Pressure: GZ and click to Add and Fluid Pressure will be Assigned to selected plates.

### G. IS 456-2000 Load Combinations

For Load Combinations click Load Cases and Details click to Add as it is added a dialog box will pop-up showing Load cases with options as Primary, Load Generation, Define Combinations and Auto Load Combinations by default Primary is selected and click Auto Load Combinations a dialog box "Auto Load Combinations" will appear now Select Load Combination Code: Indian Code, Select Load Combination category: General Structures then click Generate and Load Combinations will be generated in "Select Load Combinations"; here we first Click Double Arrow to move them in "Discarded load Combinations" and then Click 1.5 x Load, 1.2 x Load, 0.9 x Load combination and move them by Selecting and then clicking Single Arrow one by one and click to Add.

## X. MATERIAL FOR THE STRUCTURE

For Providing the Structure its material property Click on Design then click Concrete a dialog box will appear in Right Window named as "Concrete Design -Whole Structure" Select the Current: Code as IS-456 then click on Select Parameters and a dialog box will appear named as "Parameter Selection" and move Parameters from Selected Parameters to Available Parameters by Backward Double Arrow. Now, Select Cover,  $F_{y\text{ main}}$ ,  $F_{y\text{ sec}}$ ,  $F_c$ ,  $\text{Min}_{\text{ main}}$ ,  $\text{Min}_{\text{ sec}}$ ,  $\text{Max}_{\text{ main}}$ ,  $\text{Max}_{\text{ sec}}$  and then Click on the Forward Arrow to Move them to Selected Parameters and click on OK. After Selecting Parameters, it is the time to define them so click on Define Parameters and in new pop-up Dialog box "Design Parameters" click on selected parameters one by one and input the values as  $F_c = 30\text{ N/mm}^2$ , Cover = 25 mm,  $F_{y\text{ main}} =$

$415\text{ N/mm}^2$ ,  $F_{y\text{ sec}} = 415\text{ N/mm}^2$ ,  $\text{Min}_{\text{ main}} = 10\text{mm}$ ,  $\text{Min}_{\text{ sec}} = 8\text{mm}$ ,  $\text{Max}_{\text{ main}} = 32\text{mm}$ ,  $\text{Max}_{\text{ sec}} = 12\text{mm}$  and click on Assign and Close.

Now these Parameters are assigned to particular Elements and Members according to IS Code 456-2000, Click on these Parameters and Select Elements /Members and then click on Assign to Selected Beams/Columns/Plates/View.

## XI. DESIGN OF STRUCTURAL ELEMENTS/MEMBERS

In Modelling Window Click on Design then click Concrete a dialog box will appear in Right Window named as "Concrete Design -Whole Structure" Select the Current: Code as IS-456 then click on Commands and a dialog box will appear named as "Design Commands" from this Dialog box Select Design Beam then click Add, Select Design Column then click Add, Select Design Slab/Element then click Add, Select Take Off then click Add and Close.

Now, these Design Commands are assigned to a particular Element/Columns/Beams, Click on Design Beam and Select Beams and then click on Assign to Selected Beams/Columns/Plates/View. Click Yes for Surety Check.

Now, Click on Design Column and Select Columns and then click on Assign to Selected Columns. Click Yes for Surety Check.

Now, Click on Design Slab/Element and Select Plates and then click on Assign to Selected Plates. Click Yes for Surety Check.

## XII. ANALYSIS OF STRUCTURE

Finally for making Analysis of Whole Structure after all the procedure we had taken in designing of Circular Overhead Water Tank we will now Step forward towards Analysis so click on Analysis/Print a dialog box will appear "Analysis /Print Commands" in Print Options Select No Print Option and then click on Add. Now, Click on Analysis from Menu bar it will show Run Analysis so click on it and a Dialog box "STAAD analysis and Design" will run and perform Analysis for a few Seconds and if Analysis is done with No Errors, it will show three options as:

- View Output File,
- Go to Post-Processing Mode
- Stay in Modelling Mode

Choose one of them and click Done but here we will move towards View Output File and Go to Post-Processing Mode.

## XIII. CONCRETE AND STEEL TAKE OFF

Figure 01 shows the Result of Material Take-off from StaadPro

\*\*\*\*\* CONCRETE TAKE OFF \*\*\*\*\*  
 (FOR BEAMS, COLUMNS AND PLATES DESIGNED ABOVE)  
 NOTE: CONCRETE QUANTITY REPRESENTS VOLUME OF CONCRETE IN BEAMS, COLUMNS, AND PLATES DESIGNED ABOVE.  
 REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND COLUMNS DESIGNED ABOVE.  
 REINFORCING STEEL IN PLATES IS NOT INCLUDED IN THE REPORTED QUANTITY.

TOTAL VOLUME OF CONCRETE = 90.3 CU.METER

BAR DIA (in mm)	WEIGHT (in New)
8	7625
10	3710
12	19760
16	10354
20	42548
25	48838
32	11885
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*** TOTAL=	144719

997. PERFORM ANALYSIS

Figure 1: Result of Material Take-off from StaadPro

#### XIV. RESULTS OF DIFFERENT ELEMENTS OF STRUCTURE FROM STAAD PRO

Figure 2 shows the Shear in Y Direction, Figure 3 shows the Displacement, Figure 04 shows Shear Stress, Figure 5 shows the Torsion and figure 6 - 10 shows the reinforcement details in the water tank.

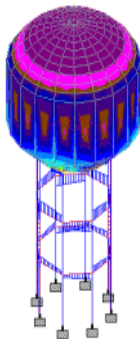


Figure 2: Shear in Y Direction

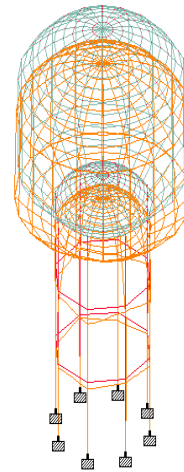


Figure 3: Displacement

Load 7: Di

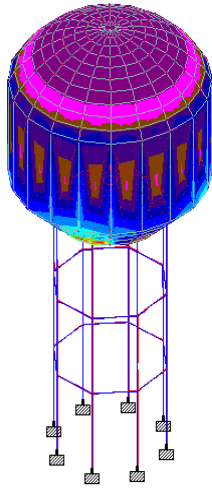


Figure 4: Shear Stress

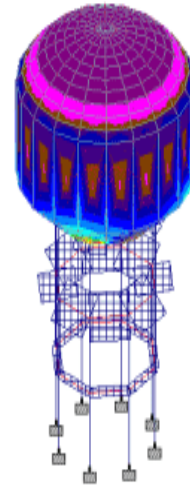


Figure 5: Torsion

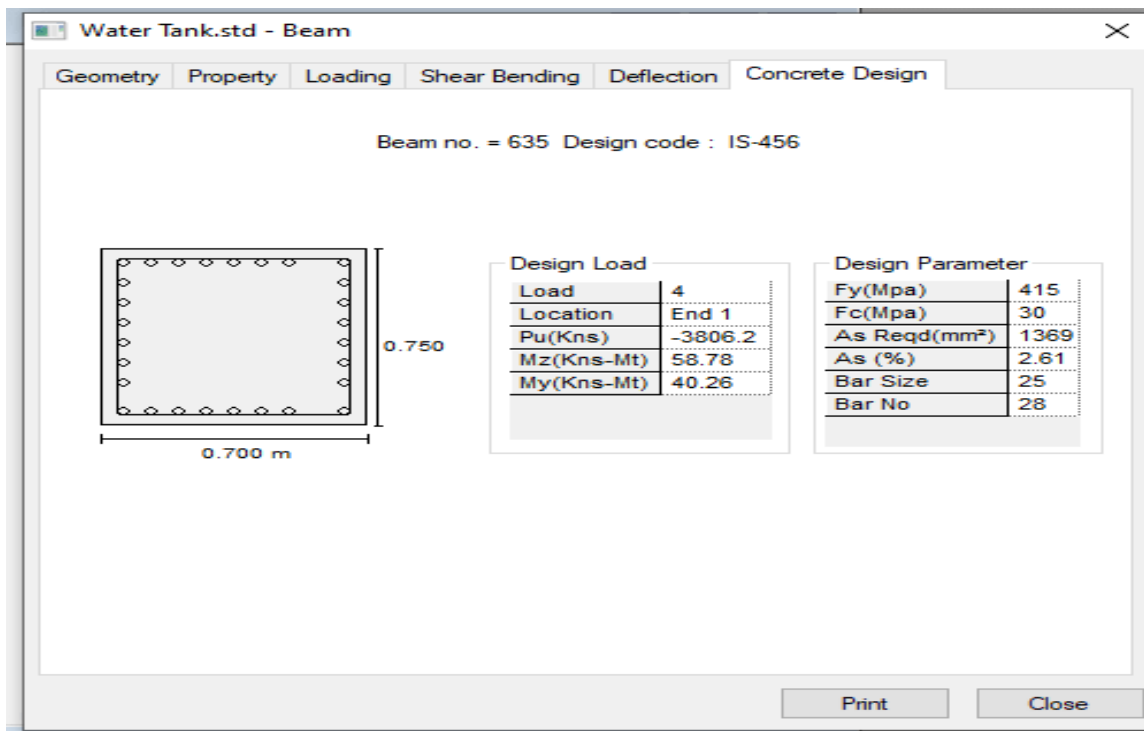


Figure 6: Column Design

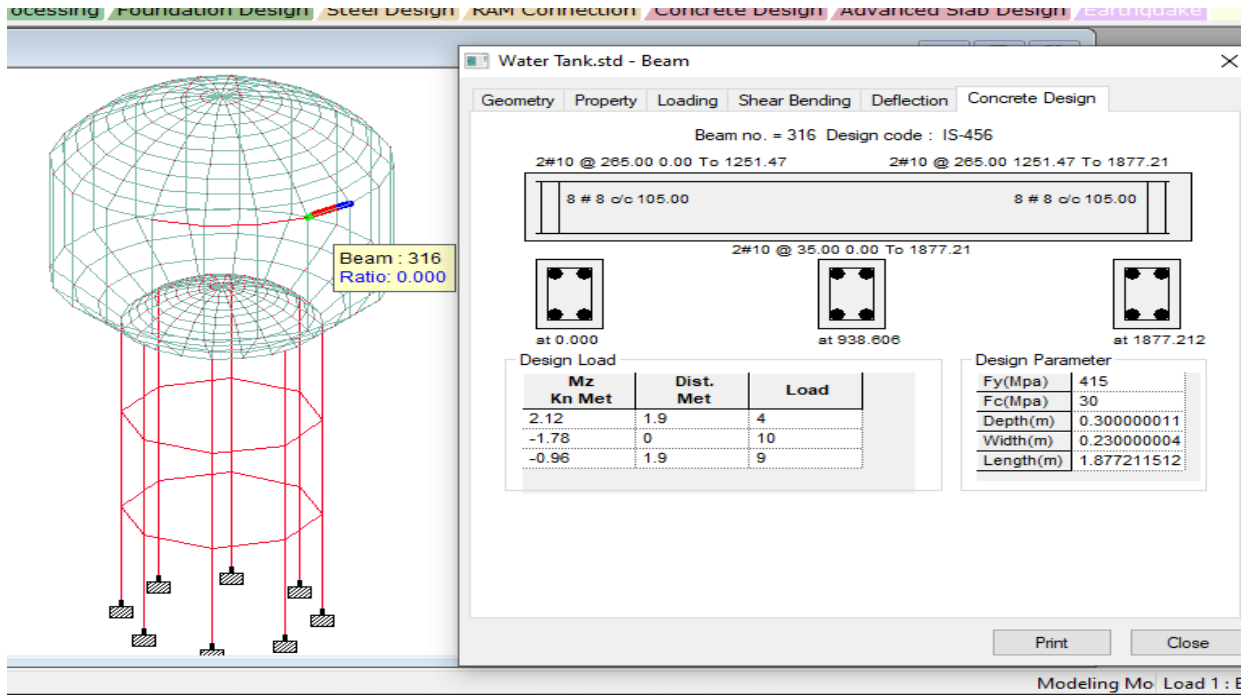


Figure 7: Top Ring Beam

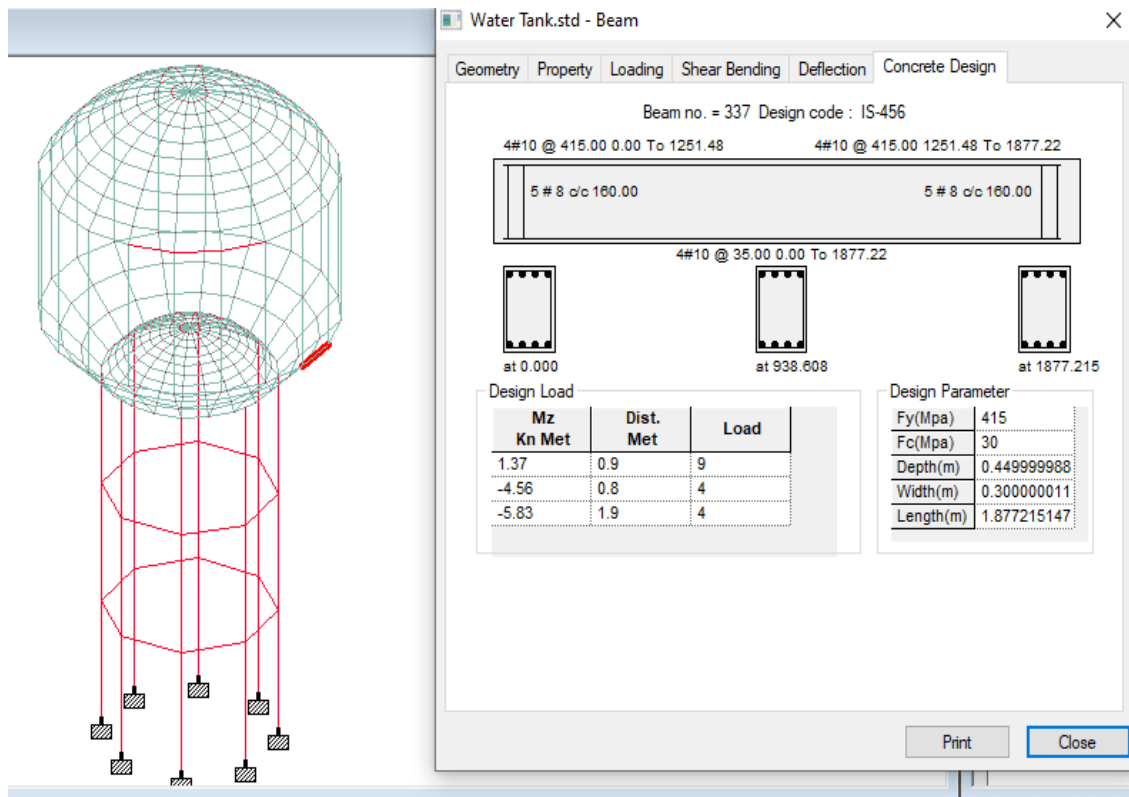


Figure 8: Middle Ring Beam



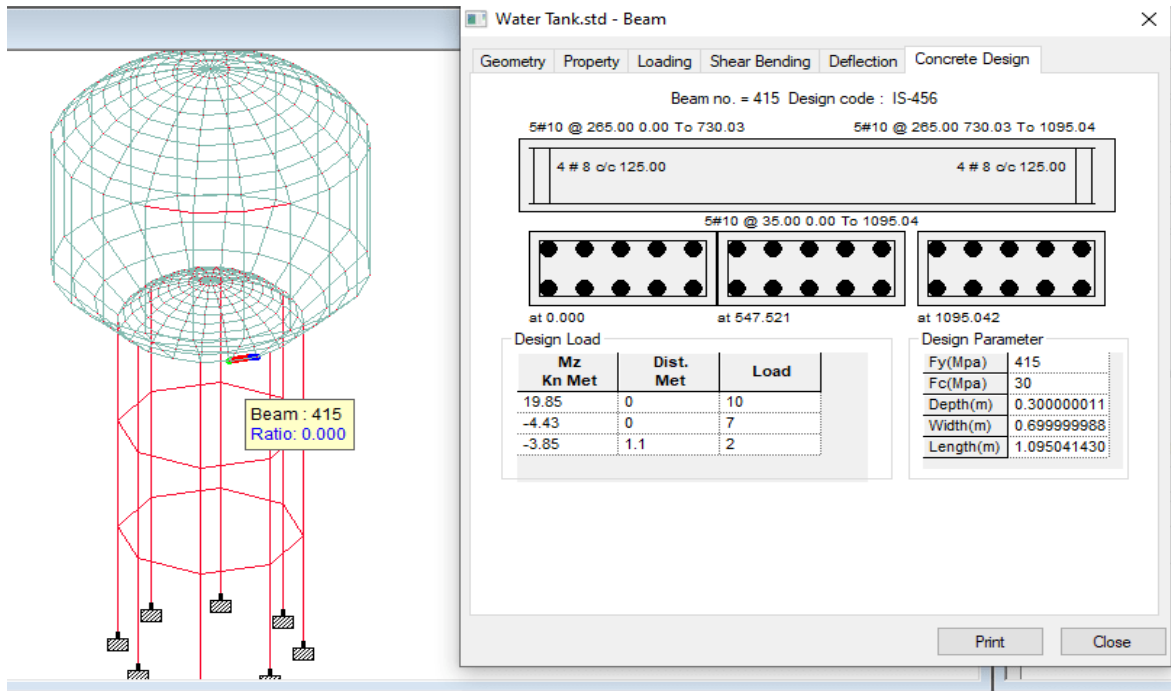


Figure 9: Bottom Ring Beam

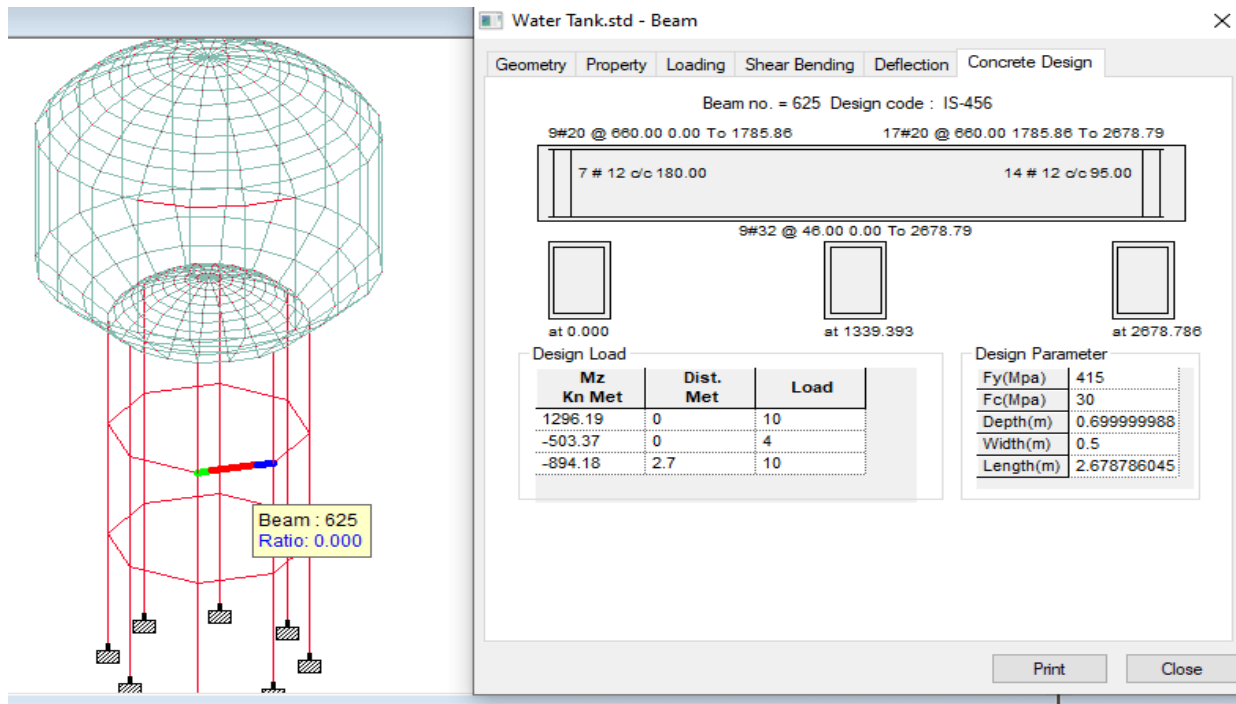


Figure 10: Bracing Beam

## XV. CONCLUSION

- This Circular Overhead Tank was designed for a capacity of about 825 m<sup>3</sup>; it has been designed by using M30 grade of concrete and HYSD bar of grade Fe415.
- The Staging or Supporting system has been designed for a height of about 50 feet.
- The design results obtained after successful completion were error free and safe.
- The design results were matched with manual calculations which showed the same amount of reinforcement.
- We concluded the safe design of this Overhead Intze water Tank after obtaining Error free design results from StaadPro.

## CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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