

DESIGN AND ANALYSIS OF INTZE WATER TANK

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering Degree in Civil Engineering

By

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**DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

APRIL 2022



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DEPARTMENT OF CIVIL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of Santhosh Kumar (38200030) carried out the project entitled "**DESIGN AND ANALYSIS OF INTZE WATER TANK**" under our supervision from December 2021 to April 2022.

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Submitted for Viva voce Examination held on 02 / 05 / 2022

Internal Examiner

External Examiner

DECLARATION

I **Santhosh Kumar** hereby declare that the Project Report entitled **DESIGN AND ANALYSIS OF INTZE WATER TANK** done by me under the guidance of Dr. Nirmala.R is submitted in partial fulfilment of the requirements for the award of **Bachelor of Engineering degree in Civil Engineering.**

DATE: 2-5-2022

PLACE: Chennai

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SIGNATURE OF THE CANDIDATE

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ABSTRACT

Water tanks are one of the important public utility and also used in industrial structure. The design of water tanks and construction methods are used by reinforced concrete in the construction areas, physical property of material, wind load and the weather conditions. Before starting the design, the suitable type of staging of tank and correct analysis of loads including statically equilibrium of structure. The design is made considering the worst possible combination of loads, moments and shears arising from vertical loads and horizontal loads acting in any direction when the tank is full as well as empty. In this project by performing the analysis and design of Intze tank, deflection shape due to hydrostatic pressure and stresses, etc. are analysed manually and by software with the assistance of staad pro and piping and collage pipeline layout and estimation of the tank been shown and analysed.

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LIST OF ABBREVIATIONS

A	-	Total area of section
A_{sc}	-	Area of the longitudinal-reinforcement (compressive)
A_{st}	-	Area of the steel (tensile.)
A_{sv}	-	The total cross-sectional dimension of stirrup legs or bent up bars Within distance S_v
$A\Phi$	-	Area of the cross-section of a bar.
α	-	inclination.
b	-	width.
D	-	depth
d	-	effective depth
F	-	shear characteristic force.
F_d	-	design load
f	-	stress
f_{ck}	-	Characteristic of compressive stress of concrete.
F_y	-	Characteristic of tensile strength of steel.
H	-	Height.
I	-	moment of inertia.
I_e	-	equivalent moment of inertia.
j	-	lever arm factor.
L	-	length.
l	-	Effective length of column or length or bond length.
M	-	Bending moment or moment.

M_r	-	Moment of resistance or radial bending moment.
M_t	-	Torsional moment.
M_u	-	Ultimate bending moment
M_θ	-	Circumferential of the bending moment
M	-	modular ratio.
N	-	depth of neutral axis.
P_a	-	Active earth pressure.
P_p	-	Passive earth pressure.
P_t	-	Percentage steel.
Q	-	shear stress due to torsion
R	-	Radius.
S	-	spacing of bars.
T	-	tensile force.
T_u	-	ultimate torsional moment.
α	-	inclination.
Γ	-	unit weight of soil
σ_{cc}	-	permissible stress in concrete.
σ_{cbc}	-	permissible compressive stress in concrete due to bending.
σ_{sc}	-	permissible compressive stress in bars.
σ_{st}	-	permissible stress in steel in tension.
μ	-	Co-efficient of friction.

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CHAPTER-1

INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

Storage water tanks and the overhead tank are used for storage of water, liquid petroleum, petroleum products and other products made of liquids. These structures are usually made with steel, reinforced and pre stressed concrete. Out of these, steel tanks are used for smaller capacities. The cost of the steel tanks is high so they are rarely used for water storages. Reinforced concrete tank is high and hence they are used for water storages. Reinforced tanks are very important because, the construction and the usage which gives more value and storage of water, they are cheap, and can be made leak proof. Usually water tanks should not cracks and not to be allowed to take place in any parts of the structure which fluids are retaining in R.C.C tanks and made water tight by using mix of concrete. Sometimes water proofing materials are also make tanks water tight. Permeability of the concrete is directly proportional to the water cement ratio. Cement content must be from 330 Kg/m³ to the 530 Kg/m³ is used to avoid shrinkage. The leakage of the tank which is more in higher head and it has been observed that head up to 15m don't cause leakage problem. Use of the high strength deformed bar of the grade 415 is highly recommended for the construction of liquid retaining structures. However mild steel bars are also used because of its property. Placing of the reinforcement is the most important in construction of ring beam and more, the main use of the small sized reinforcement's use of deformed bars lead to differential cracks. A crack width of 0.1mm has been acceptable as per the permissible value in the liquid retaining structures. While designing the liquid retaining structures is recommendation of the code book and the other properties "Code for Practice for storage of liquids- IS3370 (Part I to IV)" should be considered.

The most important part of the water tank is the design of the wind load and the lateral loading or seismic loads the wind the design has been done manually and the design also done in STAAD.PRO software the main values are taken from the code book and as per Indian standards and the water tank the water pressure main depends on the staging and the size of the tank or h/d ratio. The main objective of

the design of the Intze water tank is to have a constant supply of water in Sathyabama collage and the collage layout has been show with respect to the piping's and the water tank is constructed by the reference with respect to the clean water production takes place in STP (sewage treatment plan) and the production of water which directly goes to the water tank and then it gets supplied to the entire collage.

1.2 GENERAL

A study review's main goal is to provide the research as well as in-depth knowledge about the research that has been undertaken. This serves as the foundation for carrying out work and formulating project strategy. The research study on Design and Analysis of Intze water tank was identified in the following literature survey.

1.3 LITERATURE SURVEY

Imadabathuni et al., (2021), had completed this project on design the Intze water tank with the manual calculation and the design of the tank with the help of staad pro and had a capacity of 3 lakhs litres water capacity and made the comparison between the manual calculation and the calculated value of the staad pro and also analysed with respect to wind load and water pressure.

Marlapalle et al., (2021), had the completed the project of the analysis and the design of Intze water tank using staad pro and AutoCAD for the basic layout for the water tank they have calculated the tank for 5 lakhs litres and they have done the manual design with respect to the capacity of the tank and the design of the wind loads as not shown in the staad pro software they also concluded the h/d ratio.

Sunita Ahuja et al., (2019), Also completed the project of designing the Intze water tank using only staad pro and has the detailed design in wind load and the earthquake load and highly concentrated on the lateral displacement and with

the graph also differentiates the wind load design with respect to height of the Intze water tank with respect to staging of the tank and the columns to provide support for the tank.

Ajmal Tokhi et al., (2019), made the comparison of the and the full design of elevated water tank with respect to Intze, circular water and also with rectangular water tank with the detailed staad pro calculation of all three water tanks with respect to the capacity and all the loads acting on the water tank with help of staad pro and no manual calculations had been done and fully trusted on the calculation of staad pro.

Amandeep Singh et al., (2019), made the design of Intze water tank with the assistance of staad pro and in which the water tank is supported by the RC shaft and it was only calculated on the basis of the water pressure and the differences made by both when the water is full and when the water is drained based on the h/d ratio which is height with the width ratio.

Mohammad Quais Khan et al., (2019), made the estimation of Intze water tank using the graphical interface method and the estimated water tank has been done with this software and the detailed methodology to explain required amount of the materials is used for the construction for the water tank and the graph is also used in the total amount of concrete is used for the construction of the water tank.

Hemishkumar Pate et al., (2019), made the analysis of Intze water tanks using SAP2000 software and the software is mainly used in the structure analysis of the tank and the and they used the software to find the height of the cylindrical portion of the water tank and the manual calculation is not shown in the project all the calculation was done in the software and the conclusions was the final result was given by the software

Chetan Agari et al., (2019), has done the seismic analysis of Intze water tank and also has the different design of bracings for the water tank and which was done by staad pro software and also the water tank three dimensional view also been shown and the entire water tank also designed the gravity loadings is calculated separately when the tanks is filled and when the tank is emptied.

Issar Kapadia et al., (2017), has studied the entire design of Intze water tank with respect to wind loadings and also designed with the staad pro and also concluded that the staging height increases and the water pressure is also increases and the design of the tank is also been shown and the seismic loading is not shown and the water tank three dimension view is also been shown and also explained the advantage of Intze tank over the circular tank.

Rajkumar et al., (2017), has done the project with respect to water tank regarding response spectrum analysis of the Intze tank and the every design and analysis is done by staad pro software and they also done the time history analysis of the water tank and the water tanks has the detailed design and analysis of the structure.

Prasad Barve et al., (2017), has the detailed study of water tank with respect to the hydrostatic pressure of water present inside of the water tank and also the design of raft foundation for the water tank and also study of SBC (Safe bearing capacity) of soil for the sub-structure and the h/d ratio for the tank and the water flow and the pressure is also been shown in the project.

Jay Lakhanakiya et al., (2015), has the detailed study on the parametric study on the different types of staging and how it affects the water pressure with respect to the height and the capacity of the tank and the detailed design of the tank is also been shown and the manual calculation of the water tank is also been explained.

Kaviti Harsha et al., (2015), has the seismic design of water tank with respect to the rectangular type water tank and also explained about the staging of the water tank and the seismic design is done using the staad pro software and the detailed diagram of shear force and bending moment diagram is also been shown in the project and the seismic design is also been shown.

Sharma Abhay et al., (2014), the project mainly consist of the design of the Intze water tank and mainly concreated on the design of the wind load and the foundation of the water tank and also the shear force diagram and bending moment diagram is also been shown in the project and also has a layout of water tank and the manual design of the water tank is also been shown.

MUTHU VIJAY et al., (2014), has done the project on analysis of sloshing impact on overhead water tank and the basic design was shown in rectangular water tank and design of Intze water is also done in the staad pro software and the 3 dimensional view is also been shown and the main sloshing effect is also been shown and the seismic design of the water tank is also shown.

CHAPTER-2

AIM AND SCOPE OF INVESTIGATION AND METHODOLOGY

2.1 AIM

1. To prepare a layout of Intze type water tank in Sathyabama institute of science and technology.
2. To do Planning and 3-Dimensional elevation of Intze water tank.
3. To do Structural analysis and Design using Staad pro (Guidelines using IS codebook).
4. To do Estimation for the construction of Intze water tank.

2.2 SCOPE

1. To have a good supply of water from the STP production to the entire collage.
2. To determine water flow from the tank to the whole University.

2.3 METHODOLOGY

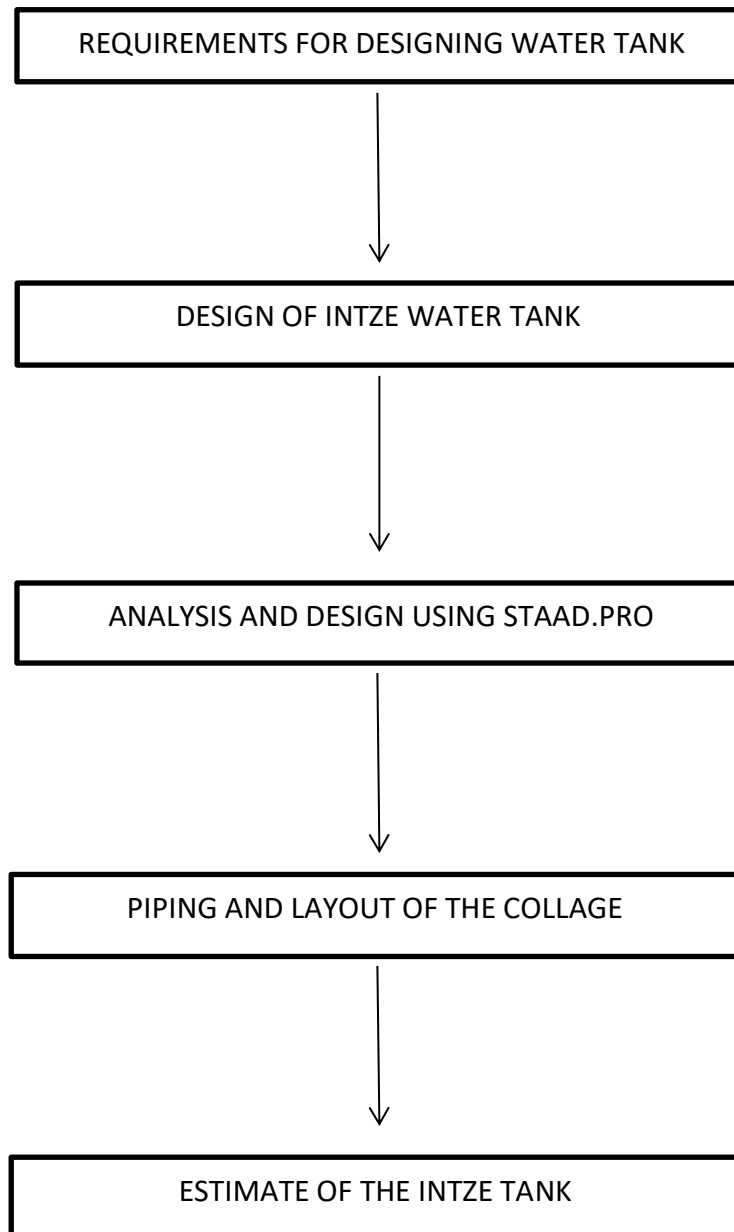


Fig 2.1: Flow chart

CHAPTER-3

DESIGN OF INTZE WATER TANK

3.1 POPULATION AND STP PRODUCTION

As per the current 2020 population in Sathyabama

$$= 1, 94,675$$

The per capita water required for a single person

$$= 135 \text{ litres per day}$$

So the total water consumption for 1, 94,675 population

$$= 1, 94,675 \times 135$$

$$= 26,281,125 \text{ litres per day}$$

As per the standard STP (Sewage treatment plan) the production of water per day is less than the original water required.

STP water purified per hour = 60,000 litres per hour

STP water purified per day = 14, 40,000 litres per hour

Approximately = 15, 00,000 litres per day

The total water production per day is 15 lakh litres per day the water can be raised into water tank two times per day

$$= (15, 00,000) / 2$$

$$= 7, 50,000 \text{ (Aprox) } 8, 00,000 \text{ litres}$$

3.2 DIMENSIONS AND STAGING

Capacity of tank = 8, 00,000 litres

Staging of water tank = 18m

Steel = Fe 415

Concrete grade = M30

Diameter of tank (D) = 15 m

Diameter of the lower Ring Beam (D_0) = 15m $\times$ 0.6m = 9m

Rise of top dome (h_1) = 2.5m

Rise of bottom dome (h_2) = 1.5m

Height of conical dome (h_0) = 2m

Height of cylindrical portion:

Capacity of Tank:

$$= \pi/4 \times (D_2 \times h) + \pi/12 \times h_0 (D_2^2 + D_0^2 + D \times D_0) - \pi/3 \times h_2^2 \times (3R_2 - h_2)$$

$$\text{Where, } R_2 = (((D/2)^2) + h^2) / (2 \times h)$$

$$= (((15/2)^2) + 1.5^2) / (2 \times 1.5) = 7.25\text{m}$$

$$800 = (\pi/4 \times 15^2 \times h) + \pi/12 \times 2 \times (15^2 + 9^2 + 15 \times 9) - \pi/3 \times (1.5^2 (3 \times 7.251.5))$$

$$\Rightarrow h = 4.00\text{m}$$

The height of the cylindrical wall for the Intze tank = 4.00 meter

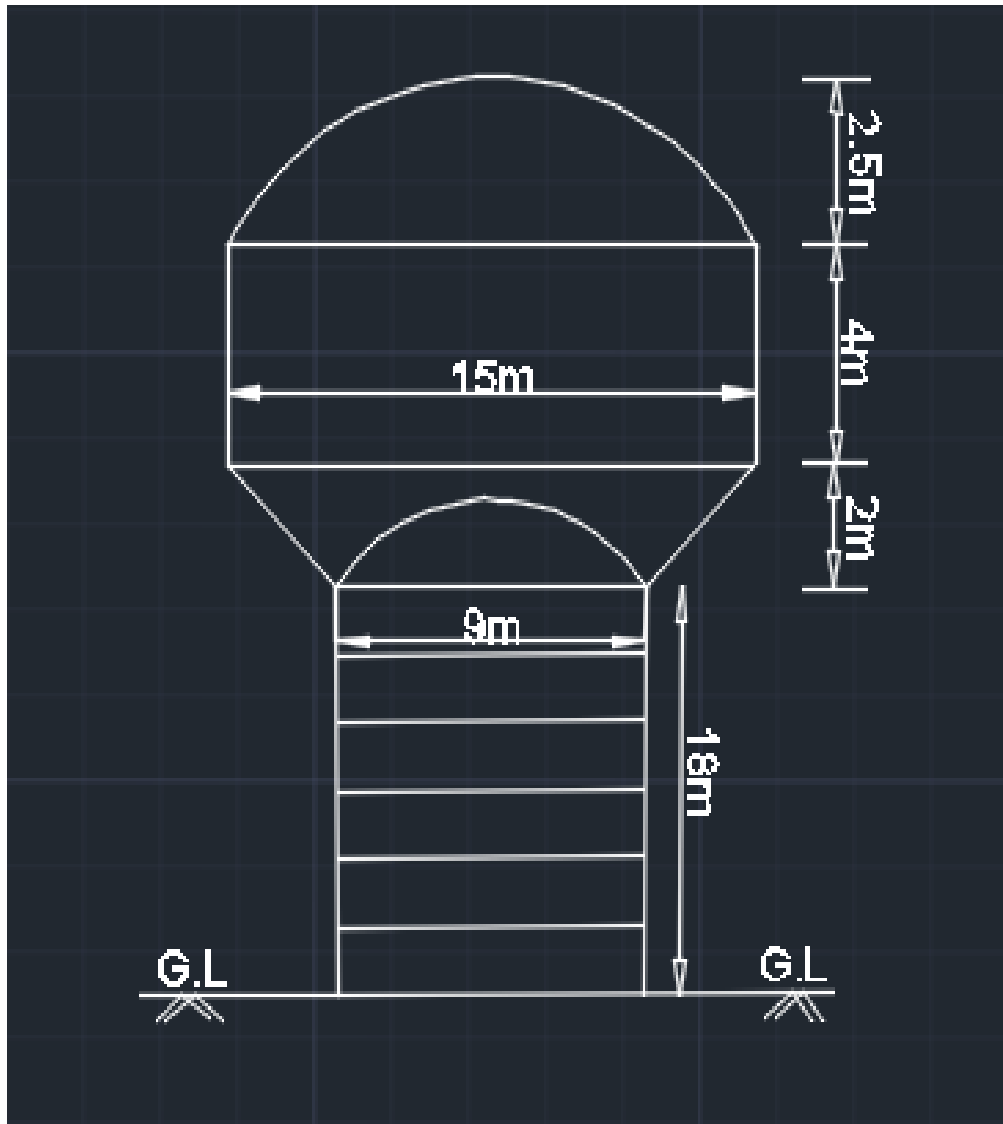


Fig 3.1 : DIMENSIONS OF INTZE TANK

The above figure 3.1 shows the dimensions of the Intze water tank and the design is done with respect to the dimensions of the tank

The design of Intze water tank has been classified into different parts and every parts has consist of it's own calculations which includes with respect to the loadings factors like wind load and seismic loadings. So the design of Intze water tank is given below.

3.3 DESIGN OF TOP DOME

As per Intze tank the tank contains two types of dome which is top dome and bottom dome. The dome is the part which makes difference from the other overhead water tanks. The top dome rise generally $1/5^{\text{th}}$ of the total length.

Provide the thickness of the roof dome as 150mm

Let the angle subtended by the top dome is 2θ

$$\therefore \sin\theta = d/2 (R_1)$$

$$\text{Where, } R_1 = ((15/2)^2 + 2.5^2) / 2 \times 2.5$$

$$= 12.5 \text{ m}$$

Therefore,

$$\theta = 1/\sin (15/2 \times 12.5)$$

$$\theta = 36.87^\circ$$

Loads =

$$\text{Dead load} = 0.15 \times 25000$$

$$= 3750 \text{ N/m}^2$$

$$\text{Live load of the top dome is} = 0.75 - 0.52 y^2 \quad (\text{from Table 2, IS: 875 part - 2})$$

$$y = h/D = 2.5/15$$

$$= 0.75 - 0.52 \times (2.5/15)^2$$

$$= 0.735 \text{ KN/m}^2$$

$$= 735 \text{ N/m}^2$$

$$\text{Total load (w)} = 3750 + 735 = 4485 \text{ N/m}^2$$

HOOP STRESS AT THE LEVEL OF SPRINGING =

$$f = wR/t ((\cos \theta) - (1/1+\cos \theta))$$

$$f = 4485 \times 12.5 / 0.15 ((\cos 36.87^\circ) - (1/1+\cos 36.87^\circ))$$

$$f = 0.091 \text{ N/mm}^2$$

HOOP STRESS AT THE CROWN =

At Crown $\theta = 0^\circ$

$$f = wR/t ((1) - (1/1+1))$$

$$= (4485 \times 12.5 / 0.15) \times 0.5 = 186875 \text{ N/m}^2 = 0.18 \text{ N/mm}^2$$

Meridional thrust of the level per meter run:

$$T1 = (wR / 1+\cos\theta) = (4485 \times 12.5 / 1+\cos 36.87^\circ)$$

$$T1 = 31145 \text{ N/m}$$

$$\text{Meridional stress} = (31145) / (150 \times 1000)$$

$$= 0.21 \text{ N/mm}^2$$

Providing nominal reinforcement

∴ Provide nominal reinforcement (0.3%)

$$A_{st} = (0.30/100) \times 1000 \times 150 = 450 \text{ mm}^2$$

∴ Providing the bars at 8 mm ϕ @ 110 mm c/c

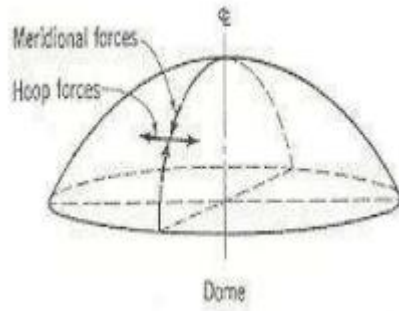


Figure 3.2: TOP DOME

3.4 RING BEAM AT TOP

The ring beam is mainly designed for the maximum bending moment and the torsional moment and to resist horizontal thrust. The top ring beam is the connection between the top dome of the tank and the cylindrical portion of the Intze tank.

$$\text{Horizontal component} = T_1 \cos \theta$$

$$= 31,145 \times \cos 36.87 = 24915 \text{ N}$$

$$\text{Hoop tension in the ring beam} = 24915 \times 15 / 2 = 186862 \text{ N}$$

$$\therefore \text{Area of steel required for hoop tension} = 186862 / 150 = 1245 \text{ mm}^2$$

Provide 6 bars 18 mm diameter

Size of the ring beam =

$$\text{Let the area of the ring beam} = A \text{ mm}^2$$

$$\text{Equivalent concrete} = A + (m-1) A_{st}$$

$$\sigma_{ct} = (T / A + (m-1) A_{st}) \quad (\text{IS : 456 _ 2000 , Cl B-1.3})$$

$$A + (m - 1) A_{st} = A + (13.33 - 1) \times 1526 = A + 18815 \text{ mm}^2$$

Limiting tensile stress of the equivalent concrete area to the 1.2 N/mm^2

$$\sigma_{ct} = (T / A + (m-1) A_{st})$$

$$= (186862 / A + 18815) = 1.2$$

$A = 136903 \text{ mm}^2$ (Provide $350 \text{ mm} \times 400 \text{ mm}$ section for ring beam)

SHEAR REINFORCEMENT FOR TOP RING BEAM =

Provide 8ϕ – 2 legged stirrups

As per IS: 456 – 2000, Cl – 26 .5.1.6

$$1) 0.7 D + 0.75 \times 400 = 300$$

$$2) 300 \text{ mm, and } S_v = ((0.87 \times f_y \times A_{sv}) / (0.4 \times b))$$

$$A_{sv} = 2 \times \pi 4 \times 82 = 100 \text{ mm}^2$$

$$\therefore S_v = (0.87 \times 415 \times 1000) / (0.4 \times 350) = 257.89 \text{ mm}$$

Provide, $S_v = 250 \text{ mm}$ and Provide 8ϕ – 2 legged vertical stirrups @ 250 mm c/c

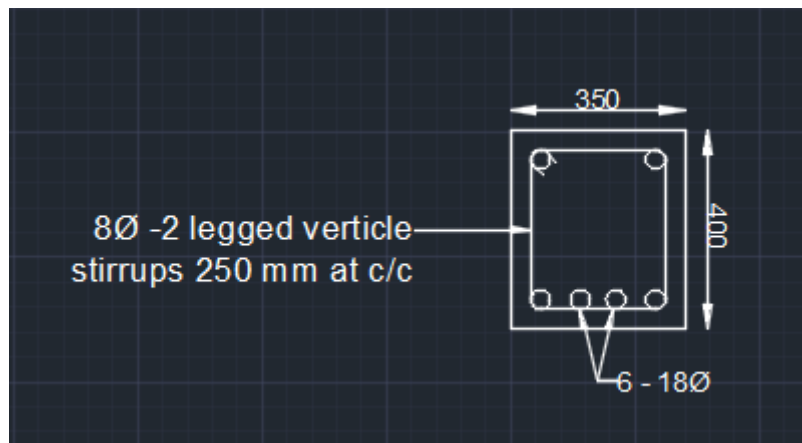


Figure 3.3: TOP RING BEAM

3.5 CYLINDRICAL WALL

The cylindrical wall is the major area where the water gets stored in the tank and the cylindrical area is the one of the best shape because of the uniform stress distribution across the area of the tank which rectangular tanks does not provide. The below calculations show the pressure and the thickness required for water tank.

Pressure intensity at the underside of cylindrical wall = $4 \times 10000 = 40000 \text{ N/m}^2$

Consider bottom of the wall as 1 m.

Hoop tension = $(Pd / 2)$

$$= (40000 \times 15 / 2) = 300,000 \text{ N}$$

$$A_{st} = (300000 / 150) = 2000 \text{ mm}^2$$

Spacing of 12 mm diameter bars Spacing

$$= (\pi / 4 \times 12^2 \times 1000) / 2000 = 56 \text{ mm}$$

Providing 12 mm ϕ bars @ 110 mm centres near each face

Thickness of the wall =

$$C_t = (T / (1000 t + (m-1) A_{st})) \text{ N/mm}^2 < 1.2$$

$$T = (\gamma_w \times h \times D / 2) = 10 \times 4.0 \times 15 / 2 = 300 \text{ KN} = 300000 \text{ N}$$

$$A_{st} = \pi / 4 \times 12^2 \times 110 = 1028 \text{ mm}^2$$

$$(300000) / (1000 \times t + (13.33-1) \times 1028) < 1.2 \text{ N/mm}^2$$

$$T = 237.32 \text{ mm}$$

$$T = 300 \text{ mm (thickness of wall } t = 300 \text{ mm)}$$

$$\text{Distribution steel} = 0.3/100 \times (300 \times 1000) = 900 \text{ mm}^2$$

$$\text{Spacing of 8 mm } \phi \text{ bars} = 50 \times 1000 / 900 = 55 \text{ mm}$$

Provide 8 mm ϕ bars at 100 mm centres near each face.

Check for compressive stress at the underside of the cylindrical wall.

Vertical component of $V_1 = T_1 \sin \theta$

$$= 31145 \times \sin 36.870 = 18687 \text{ N/m}$$

Weight of the wall = $0.3 \times 4.0 \times 25000 = 30000 \text{ N/m}$

Weight of the ring beam = $0.35 \times 0.4 \times 25000 = 3500 \text{ N/m}$

$V_2 = \text{Total vertical load per meter} = 18687 + 30000 + 3500 = 52187 \text{ N/m}$

Compressive stress = $52187 / 300 \times 1000 = 0.173 \text{ N/mm}^2$

$$= 0.18 \text{ N/mm}^2$$

This stress being the low profile for the nominal vertical stress at the 0.3 % large integer area.

$\therefore \text{Vertical steel} = (0.3 / 100 (300 \times 1000)) = 900 \text{ mm}^2$

Spacing of 8 mm ϕ bars = $(\pi / 4 \times 8^2 \times 1000) / 900$

Provide of 8 mm ϕ bars at 100 mm c/c.

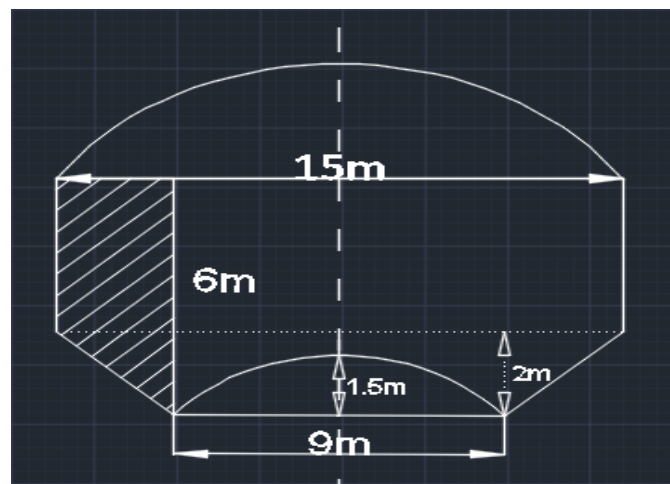


Figure 3.4: CYLINDRICAL WALL

3.6 RING BEAM AT B

The bottom ring beam where the maximum bending moment and the torsional moment is high due to the cylindrical portion is stays above the ring beam so the maximum thrust takes place in the bottom ring beam.

Let T_2 be the thrust per meter exerted by the conical slab at junction B

Resolving vertically at B,

$$T_2 \sin \alpha = V_2 = 52187 \text{ N/m}$$

$$\tan \alpha = 2/3 = 0.67, \alpha = 33.69^\circ, T_2 = 52187 \text{ N/m.}$$

Resolving horizontally at B,

$$H_2 = T_2 \cos \alpha = V_2 \cot \alpha = (52187/0.67) = 77891 \text{ N/m}$$

This horizontal load H_2 will produce a hoop tension at ring beam B

$$\begin{aligned} \text{Hoop tension } H_2 &= H_2 \times (d/2) = (77891 \times (15/2)) \\ &= 584182 \text{ N} \end{aligned}$$

Let the ring beam be 1000mm deep

$$\begin{aligned} \text{Water pressure on the ring beam} &= 1000 \times 4.0 \times (900/1000) \\ &= 36000 \text{ N/m} \end{aligned}$$

$$\begin{aligned} \text{Hoop tension with water pressure} &= 36000 \times (15/2) \\ &= 270000 \text{ N} \end{aligned}$$

$$\therefore \text{Total hoop tension} = 584182 + 270000 = 854182 \text{ N}$$

$$\therefore \text{Steel for hoop tension} = (854182/150) = 5694 \text{ mm}^2$$

Provide 24 mm ϕ bars,

$$\text{Number of bars required} = 5694 / ((\pi / 4) \times 24^2) = 12.59 \text{ bars}$$

Provide 13 bars of 24 mm diameter.

Let Area of ring beam section be A.

Equivalent concrete area = $A + (m-1) \times A_{st}$

$$= A + (13.33-1) \times 6333 = A + 78085$$

Limiting tensile stress on the concrete area to 1.2 N/mm^2

$$= (854182)/(A+78085) = 1.2$$

$$A = 633734 \text{ mm}^2$$

Provide the Ring beam (B) dimensions of $900 \text{ mm} \times 950 \text{ mm}$ section.

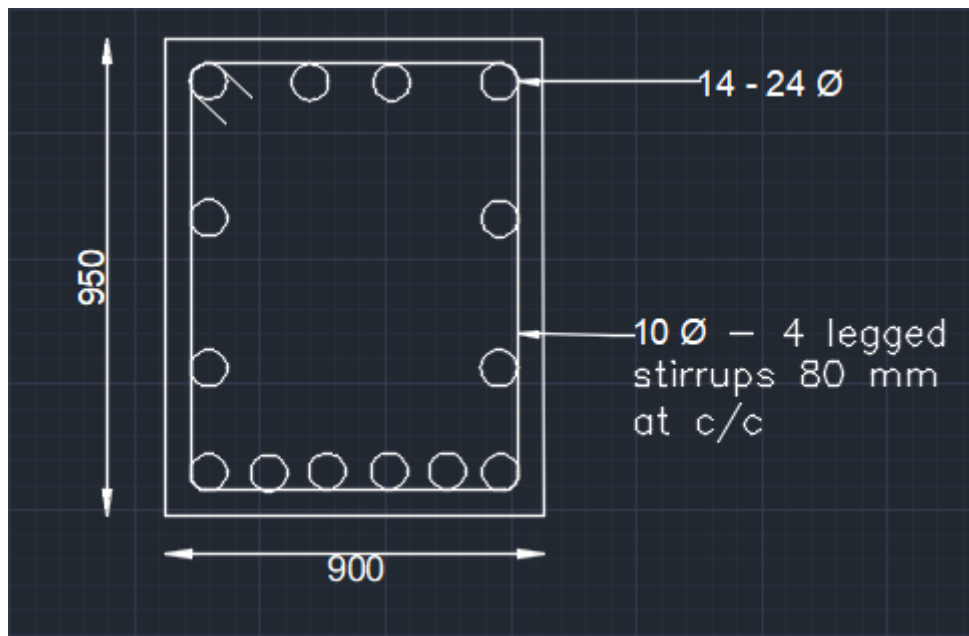


Figure 3.5: BOTTOM RING BEAM

3.7 DESIGN OF CONICAL SLAB

The Frustum portion of water tank which helps in storage of water and the most pressure, stresses and loads acting in the joint portions of conical slab and bottom dome. The Conical slab should be designed for reasons are as follows:

- a) Hoop tension
- b) Bending as it spans on a sloping slab from ring beam at 'B' till the ring girder at 'C'

Design for hoop tension =

The hoop tension on the conical slab is given by $= (W_w + W_s / 2 \pi) + ((W_w / 2 \pi) \tan \alpha)$

Where,

W_w = weight of water resting on conical slab.

α = inclination of the conical slab with the horizontal

W_s = weight of the conical slab.

Area of water section standing on the conical slab $= 3/2(4 + 6) = 15 \text{ m}^2$

$\bar{x} = (4 \times 3) + ((3 \times 2)/3) 15 = 0.934 \text{ m}$

Weight of water resting on the conical slab

$$W_w = \gamma_w \times A \times 2\pi \times (9/2 + \bar{x})$$

$$= 1000 \times 15 \times 2\pi \times (9/2 + 0.934)$$

$$= 5121424 \text{ N}$$

$$\text{Length of sloping slab} = \sqrt{(3^2 + 2^2)}$$

$$= 3.6055 \text{ m}$$

Thickness of sloping slab = 300 mm.

$$\begin{aligned}\text{The weight of conical slab} &= 3.6055 \times 0.3 \times 25000 \times 2\pi \times (15/2 + 9/2) \\ &= 1019431 \text{ N}\end{aligned}$$

Therefore,

$$\begin{aligned}\text{Hoop tension} &= ((5121424 + 1019431)/2\pi) + ((5121424)/2\pi) \times 2/3 \\ &= 1194964.91 \text{ N}\end{aligned}$$

$$\text{Hoop for total conical area} = (1194964.91)/150 = 7966.43 \text{ mm}^2$$

So providing 35 bars of 20mm diameter

Design of bending moment =

$$\begin{aligned}\text{Load/meter width of conical slab} &= (W_w + W_s) / (2\pi \times \text{mean radius}) \\ &= (5121424 + 1019431) / (2\pi \times 6) \\ &= 162891 \text{ N}\end{aligned}$$

$$\begin{aligned}\text{Max bending moment} &= wl/8 \\ &= (162891 \times 3) / 8 \\ &= 61084 \text{ Nm}\end{aligned}$$

$$\begin{aligned}\text{Now, Axial compression } (T_2) &= V_2 / \sin \alpha = 52187 / \sin 33.69^\circ \\ &= 94081.6 \text{ N}\end{aligned}$$

Providing 20 mm dia bars at clear covers of spacing 25 mm.

$$\text{Effective depth} = 300 - 25 - 10 = 265 \text{ mm.}$$

Distance between the centre of section and the centre of steel =

$$X = d - (t/2) = 265 - (300/2) = 115 \text{ mm}$$

$$\text{Resultant bending moment of the slab} = M + T_2 \times$$

$$= (61084 \times 10^3) + (94081.6 \times 115)$$

$$= 66089125 \text{ Nmm}$$

$$A_{st} = M / (\sigma_{st} \times j \times d) = 66089125 / 190 \times 0.86 \times 265 = 1526 \text{ mm}^2$$

$$\text{Spacing } 20 \text{ mm dia bar} = (\pi / 4 \times 20^2 \times 1000) / 1526 = 205 \text{ mm}$$

Providing 20 mm ϕ bars @ 200 mm c/c

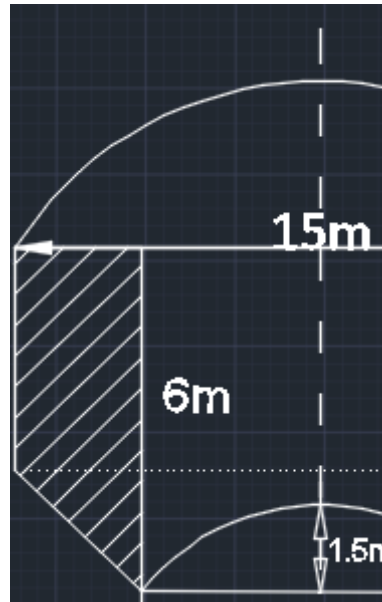


Figure 3.6: CONICAL SECTION OF THE TANK

3.8 BOTTOM DOME

The bottom dome is the connection between the conical portion of water tank and the circular girder of the tank where the thrust is high and every load is transmitted to the bottom dome and transmitted to the lower portions of water tank.

Span of the bottom dome = 9 m

Rise from bottom the dome = 1.5 m

Now finding the radius (R)

$$R = (D/2)^2 + h^2 / (2 \times h)$$

$$= (9/2)^2 + 1.5^2 / (2 \times 1.5)$$

$$= 7.5 \text{ m}$$

Let the 2θ be angle subtended by the bottom dome

$$\sin\theta = (D/2) / R = 0$$

$$\theta = 36.86^\circ$$

$$\text{Loads acting on the bottom dome} = 25000 \times 0.3 = 7500 \text{ N/m}^2$$

Weight of water resting on the bottom dome =

$$= \gamma_w \left[\pi / 4 \times d^2 \times h - (\pi \times h_c) / 3 \right] (3R - h_c)$$

$$= 1000 \left[\pi / 4 \times 9^2 \times 6.0 - (\pi \times 1.5) / 3 \right] (3 \times 7.5 - 1.5)$$

$$= 3805254 \text{ N}$$

$$\text{Area of dome surface} = 2 \times \pi \times R \times h = 2 \times \pi \times 7.5 \times 1.25 = 70.68 \text{ m}^2$$

$$\text{Load intensity to weight of water} = 3805254 / 70.68 = 53838 \text{ N/m}^2$$

$$\text{Total load intensity of water} = 53838 + 7500 = 661338 \text{ N/m}^2$$

$$\text{Meridional thrust} = (WR / 1 + \cos\theta)$$

$$= (61338 \times 7.5 / 1 + \cos 36.86^\circ)$$

$$\text{Meridional thrust} = 255560 \text{ N/m.}$$

$$\text{Meridional compressive stress} = 255560 / 300 \times 1000 = 0.85 \text{ N/mm}^2$$

$$\text{Hoop stress} = WR / t (\cos\theta - (1 / 1 + \cos\theta))$$

$$= 61338 \times 7.5 / 0.3 (\cos 36.86^\circ - (1 / 1 + \cos 36.86^\circ))$$

$$= 0.375 \text{ N/mm}^2$$

$$\text{Hoop stress at the crown } \theta = 0$$

$$\text{Hoop stress} = 0.767 \text{ N/mm}^2$$

Stresses are low and hence provide nominal 0.3% steel

Provide 8 mm bars @ 100 mm spacing

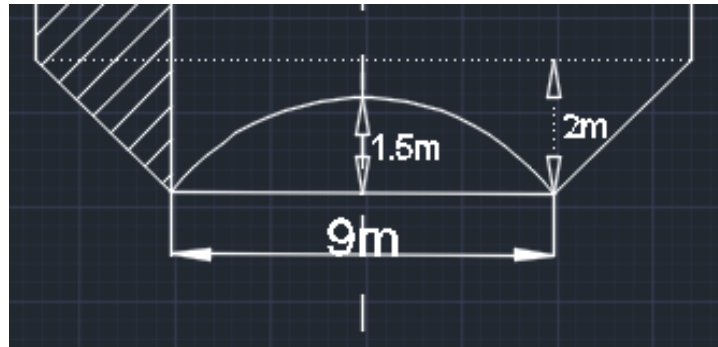


Figure 3.7: BOTTOM DOME

3.9 CIRCULAR GIRDER

The circular girder is the place where the staging of water tank takes place where the bottom dome come in contact with the circular girder and the above the tank load get transmitted to the circular girder of the tank. The below calculation shows the dimension of circular girder and the calculation of bending moment is shown.

The total loads acting on the circular girder of the tank: -

Weight of water, w_1 = conical slab + dome

$$= 5121424 + 3805254 = 8926678 \text{ N}$$

Weight, w_2 = top dome and side wall

$$= \sqrt{2} \times 2\pi \times D/2$$

$$= 52187 \times 2 \pi \times 15/2$$

$$= 2459254 \text{ N}$$

Weight of the ring beam at B, w_3

$$= 0.75 \times 0.95 \times 25000 \times 2\pi \times 4.0$$

$$= 447676 \text{ N}$$

Weight of lower dome, $w_4 = 25000 \times 0.3 \times 70.68$

$$W_4 = 530100 \text{ N}$$

Weight of conical wall, $w_5 = 1019431 \text{ N}$

Total load, $W = w_1 + w_2 + w_3 + w_4 + w_5$

$$= 13383139 \text{ N}$$

Providing 8 numbers of columns:

- Max positive bending moment $= 0.00416Wr$
 $= 0.00416 \times 14108730 \times 4.5 = 264115 \text{ N}$
- Max Negative bending moment $= 0.0083Wr$
 $= 0.0083 \times 14108730 \times 4.5 = 526961 \text{ Nm}$
- Max. torsion of the tank $= 0.0006 \times W \times r = 0.0006 \times 14108730 \times 4.5 = 38093 \text{ Nm}$

Shear force at support $= (W/2 \times \text{Number of columns})$

$$= (14108730) / (2 \times 8)$$

$$= 881795 \text{ N}$$

DESIGN AT SUPPORT SECTION =

Equating the moment of resistance to B.M at support

$$0.913 bd^2 = M_{\max}$$

$$= (0.913) \times (750) \times d^2 = (526961 \times 1000)$$

$$d = 880 \text{ mm}$$

Overall depth of beam $= 905 \text{ mm}$ with clear cover 25 mm

Equivalent shear force $= S_e = S + 1.6 \times T / b$

$$= 881796 + 1.6 \times (38093 \times 10^3 / 750) = 963061 \text{ N}$$

Equivalent nominal shear stress $\tau_{vc} = S_e / bd = 963061 / (750 \times 880) = 1.46 \text{ N/mm}^2$

Maximum shear stress $\tau_{\max} > \tau_v$

$\tau_{\max} = 2.2 \text{ N/mm}^2$ (for M30 concrete) Hence safe

Provide longitudinal and transverse reinforcement

Longitudinal reinforcements = 3164 mm^2

Providing 12 bars of 20 mm diameter of rods.

Transverse reinforcements = 1450 mm^2

Providing 6 bars of 18 mm diameter rods

3.10 COLUMNS AND BRACINGS

The columns are the connection between the foundation and the staging of water tank or circular girder of the tank. The column also helps in the load transmission from the tank to the earth surface the total height of column is 18meters.

Vertical load on a single column at the top = $14108730 / 8 = 1763592 \text{ N}$.

Let α be inclination of the column with its vertical

$\tan \alpha = 1/12$, $\alpha = 4.76^\circ$

$\cos \alpha = 0.99$ and $\sin \alpha = 0.83$

Actual length of column = 18 m.

Providing 500 mm diameter for column

Weight of column = $\pi / 4 \times 0.52 \times 18 \times 25000 = 183783 \text{ N}$

Total vertical load = $1763592 + 183783 \text{ N} = 1947375 \text{ N}$

Corresponding axis load = $1947375 / 0.995 = 1957160 \text{ N}$

Weight of water in tank = 8926678

Weight of water transmitted to one column = $8926678 / 8 = 1115834 \text{ N}$

Vertical load on one column when the tank is empty = $1947375 - 1115834 = 841326$ N

∴ Corresponding axial load = $841326/0.996 = 844705$ N

The brace beams are the beams which connects between two columns these help in the transmission of loads and helps the column to be rigid so that deformation does not occurs in the column while the loading transmission takes place.

The conditions of maximum B.M of brace beams

Moment in brace BC = moment for the column × (sec 45)

$$= 219536.4 \times \sqrt{2} = 310471 \text{ Nm}$$

Providing (300 × 500) mm section and designing with doubly reinforcement beam with equal steel both at top and bottom,

$$A_{sc} = A_{st} = (310471 \times 1000 / 220 \times 420) = 3360 \text{ mm}^2$$

Providing 6 bar of 20mm as diameter.

Shear force for brace = (B.M. for brace/ 0.5 × span of brace)

$$= (310471 / 0.5 \times 3.518) = 176504 \text{ N}$$

3.11 GRAVITY LOADINGS

The loads acting on water tank are wind load seismic load and also the gravity load which affects the water by its staging condition if the staging of water tank. The design and calculation of the wind, seismic and gravity are show below

Height of column = 18m

No. of column = 8

Dia. of column = 500 mm

No. of braces = 5

Size of braces = 300 × 500 mm

a) from container

When full = 14108730 N When empty = 4663689 N

b) Weight of column = $8 \times \pi/4 \times 0.52 \times 12.04 \times 25$

$$= 472809.7 \text{ N}$$

c) Weight of braces

Clear length of braces between two column = $2 \times 10.5 \times \sin 22.50 - 0.5$

$$= 3.518 \text{ m}$$

Weight of braces = $3.518 \times 0.3 \times 0.5 \times 25 \times 5 \times 8 = 527700 \text{ N}$

Total weight of staging = $472809.7 + 527700 = 1000509.7 \text{ N}$

3.12 WIND LOADS

Terrain category – 2

Type of structure – class A

Basic wind speed of South – East India V_b = more than 50 m/sec

Design wind speed of the water tank, $V_z = V_b K_1 K_2 K_3$

Rise coefficient $K_1 = 0.89$; from the table -1 of IS : 875 -1987 part – 3

Terrain height factor $K_2 = 1.12$; from the table -2 of IS : 875 -1987 part – 3

Topography factor, $K_3 = 1$; for slope $< 30^\circ$, as per cl.5.3.1 IS : 875 -1987 part –3

Design speed, $V_z = 55 \times 0.89 \times 1.12 \times 1 = 54.82 \text{ m/sec}$

Design wind pressure , $P_z = 0.6 V_z^2 = 1803 \text{ N/m}^2$

Reduction factor = 0.7

Wind force of the top of the dome and cylindrical wall

$$= (4.0 + 2.5/2) \times 15.6 \times 1803 \times 0.7 = 20824 \text{ N}$$

Wind force on the circular wall = $(22+10.5/2) \times 2 \times 1803 \times 0.7 = 55537 \text{ N}$

Acting at 18 m above the base

Wind force on circular girder of the water tank = $0.905 \times 10.5 \times 1500 \times 0.7 = 9978 \text{ N}$

Acting at 15m, 12m, 9m, 6m, 3m above the base which has columns and bracings

Wind force on column and braces

= $0.7 \times (5 \times 0.5 \times 12.04 + 7 \times 10.5) \times 1535 = 71831 \text{ N}$

Acting at 6.0 m above the base

Total moment of the wind pressure in the base of the water tank

= $(96,383 \times 16.9) + (28,045 \times 13.04) + (9,978 \times 12.04) + (71,831 \times 6.02)$

= 2547137 Nm

Vertical load on any column due to wind load = $(M.x) / \sum x^2$

$$\sum x^2 = 121.0 \text{ m}^2$$

Maximum wind load force of the most leeward force and the most windward side of the water tank.

= $2547137 \times 5.5 / 121$

= 1157798.0 N

Maximum wind load force in the column

= $((2547137 \times 5.5) / 125) \times (5.5 / \sqrt{2})$

= 81868.0 N

Consider the loads of windward in the column and the design of column with respect to the wind loadings.

The vertical loads, horizontal components and the loads are heavily impacted by the wind loads.

$$\text{Vertical load due to the wind load} = 1822694 + 115778 = 1938472 \text{ N}$$

Horizontal component of the axial forces caused by the wind load

$$= (2 \times 115779 \times 0.0996) + (4 \times 81868) \times (0.0996 \times 1 / \sqrt{2}) = 46128 \text{ N}$$

$$\text{Horizontal force at base} = (96383 + 28045) + (9978 + 71831) - 46127 = 160119 \text{ N}$$

$$\text{Horizontal shear per column} = (160119) / 8 = 20013.75$$

∴ Maximum bending moment for the column

$$= (20013.75 \times 3.01) / 2 = 30121 \text{ Nm}$$

3.13 SEISMIC DESIGN AND IT'S CROSS-SECTION

Considering the 1.5 percent of longitudinal steel in the column

$$\begin{aligned} \text{The equivalent area of the column in tank} &= \pi / 4 \times 500^2 \times (1 + (13.32 - 1) \times 0.015) \\ &= 232664 \text{ mm}^2 \end{aligned}$$

$$\text{Equivalent size of column} = \sqrt{232665 / (\pi / 4)} = 544.3 \text{ mm},$$

$$I_r = \pi / 64 \times 5502 = 4.4918 \times 10^9 \text{ mm}^4$$

$$E = 500 \sqrt{30} = 2.7386 \times 10^4 \text{ MPa}$$

Case – 1: When the tank is full condition

$$W_f = (14108730 + 894969.7) / 3 = 14407054 \text{ N}$$

$$T_f = 0.732 \text{ sec}$$

$$\text{Seismic force for the tank} = 0.081 \times 1440705 = 116972.35 \text{ N}$$

Case – 2 : When tank is empty condition

$$W_f = 4663687 + 894969.76 / 3 = 4962014 \text{ N}$$

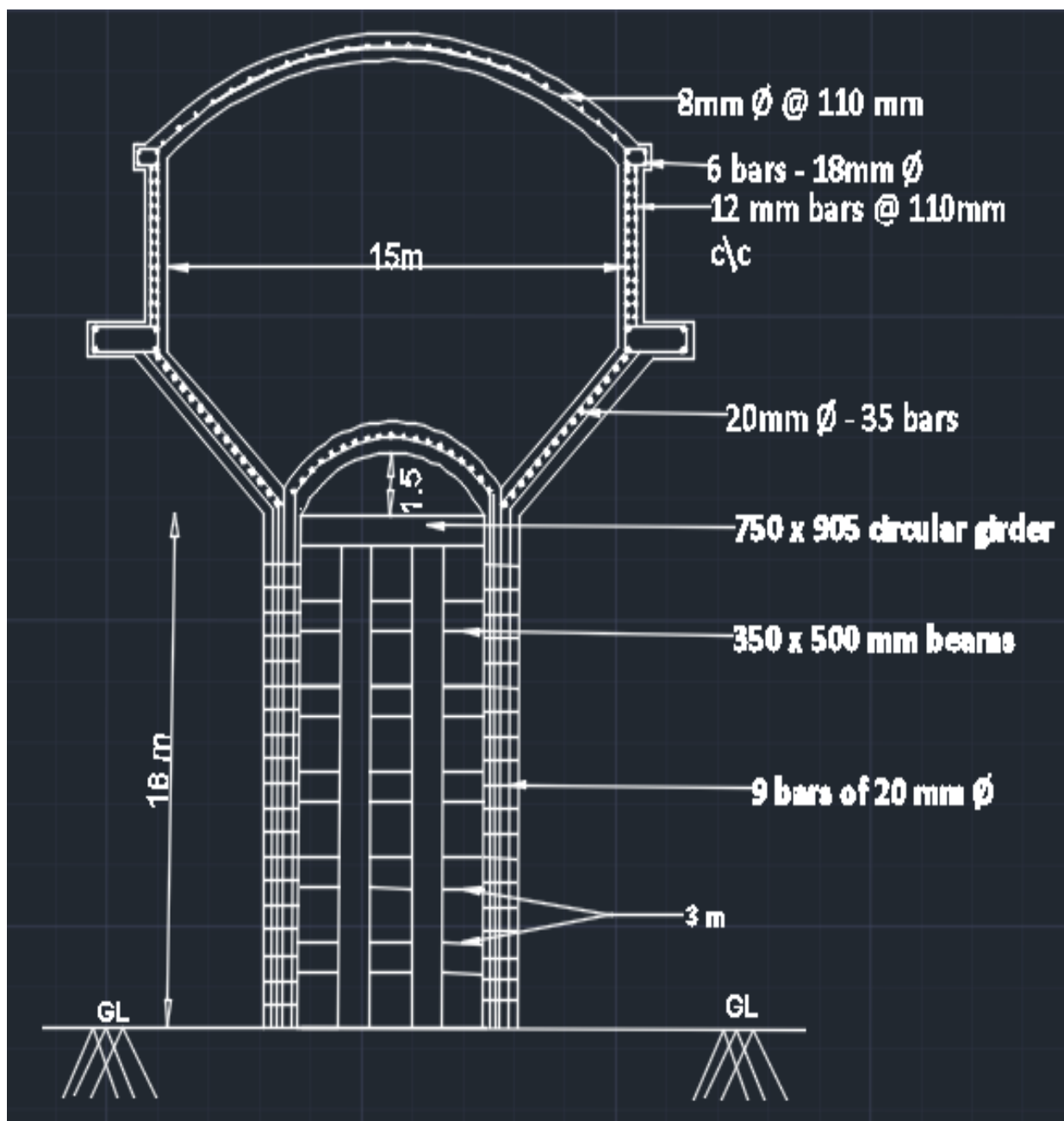
$T_f = 0.430 \text{ sec}$

Seismic force = $0.096 \times 4962012 = 4763254 \text{ N}$

Shear force per column = $(1166971.35) / (8) = 145871.47 \text{ N}$

Max bending moment of the column = $(145871.47) \times (3.01/2) = 219536.49 \text{ Nm}$

Figure 3.8: WATER TANK AND IT'S CROSS-SECTION



CHAPTER- 4

DESIGN OF INTZE TANK WITH STAAD.PRO

The software using for the design and the analysis of the water tank is done by Staad.Pro Vi8 software and the design of cross-sections with the bending moment and shear force can be found using with the help of the software.

4.1 DIMENSIONS OF WATER TANK

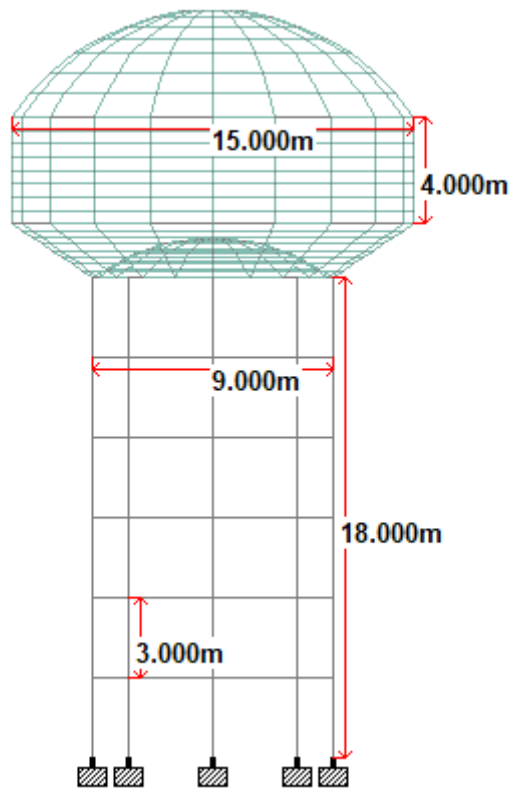


Figure 4.1: DIMENSIONS OF INTZE WATER TANK

The above figure 7.1 shows the dimension of the water tank which is going to be used the further analysis of the water tank

4.2 3-DIMENSIONAL VIEWS

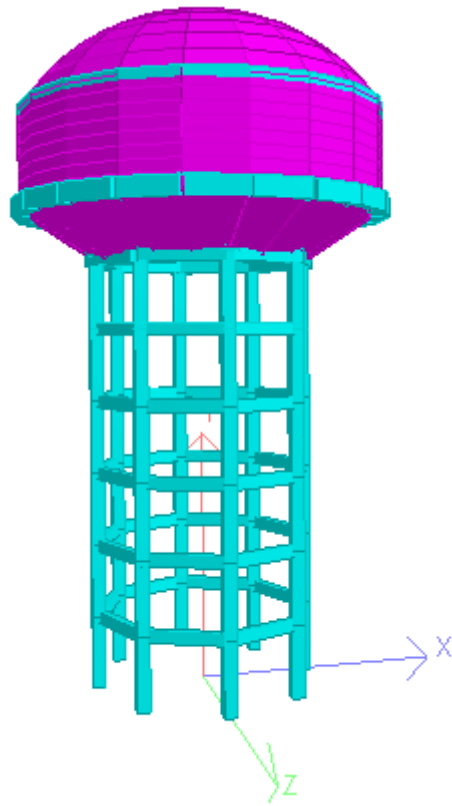


Figure 4.2: 3-DIMENSIONAL VIEW OF INTZE TANK

The above figure 4.2 shows the 3-dimensional view of the water tank which is going to be used for the further analysis of the Intze water tank.

4.3 LOADINGS

The loadings are the wind load, cross-section of the tank and the loads due to the water pressure of the tank. These loadings are applied with the help of staad pro and the loadings have been analysed by running the analysis in the staad pro.

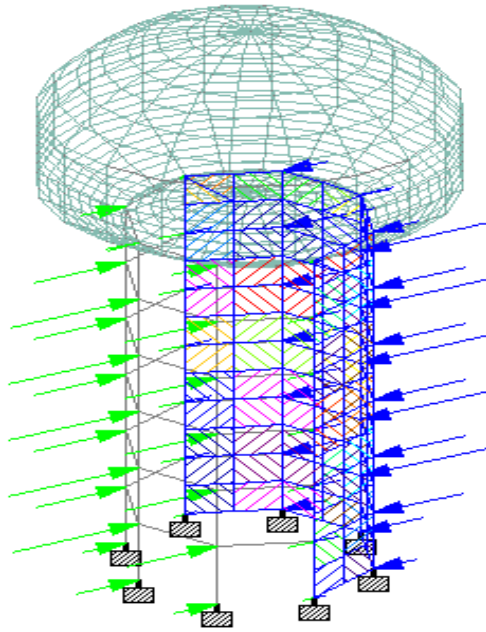


Figure 4.3: WIND LOAD ACTING IN FORWARD DIRECTION

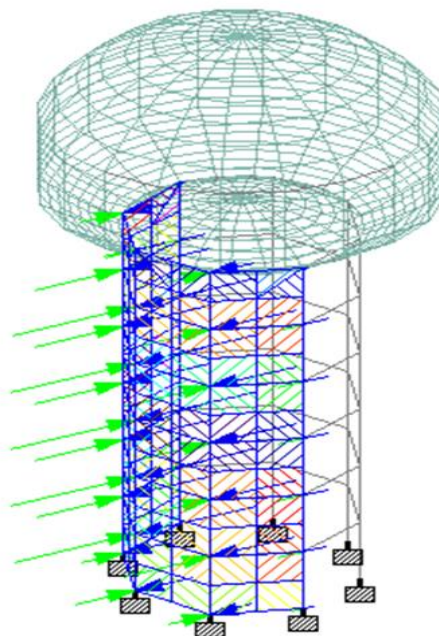


Figure 4.4: WIND LOAD ACTING IN LEEWARD DIRECTION

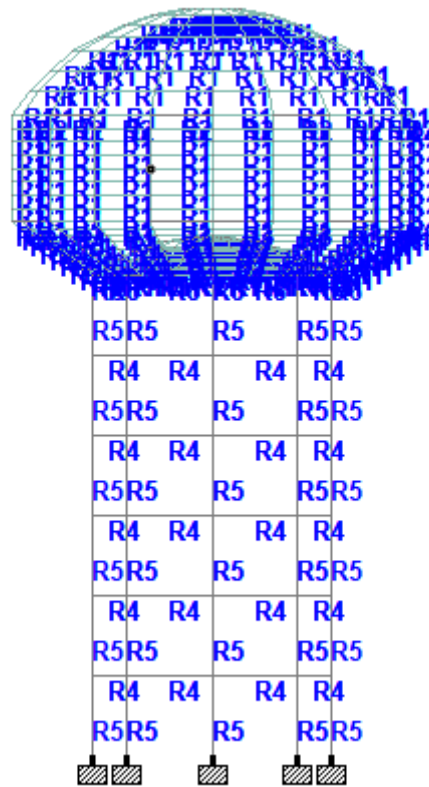


Figure 4.5: CROSS-SECTION OF WATER TANK

The above figure 4.3 shows the wind load acting on the water tank in terms of forward direction and the figure 4.4 shows the wind load acting on the water tank in leeward direction and figure 4.5 shows the cross section of the tank.

4.4 POST-PROCESSING

In this process the Bending moment diagram, Shear force diagram, Axial force diagram and the Absolute pressure diagram can be seen in the post-processing diagram. These diagrams are can be determined by after running the analysis of the staad pro and the bending moment values and other loading conditions can be verified.

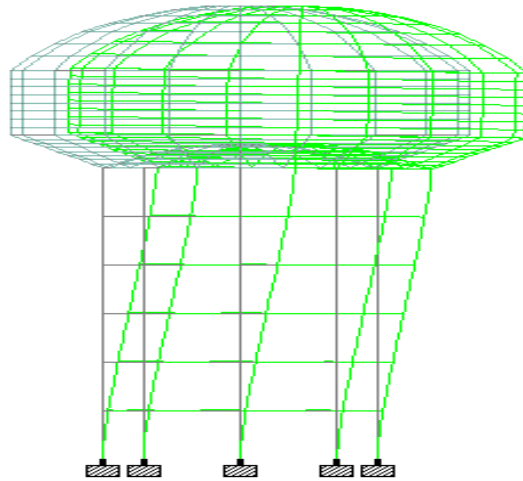


Figure 4.6: DISPLACEMENT OF THE WATER TANK

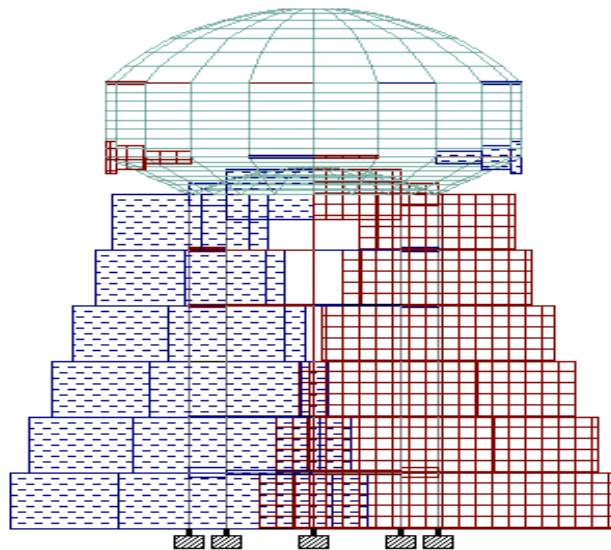


Figure 4.7: AXIAL FORCE OF THE WATER TANK

The above figure 4.6 shows the displacement of water tank and the figure 4.7 shows the axial force of the water tank. These values can be obtained only by the post processing method.

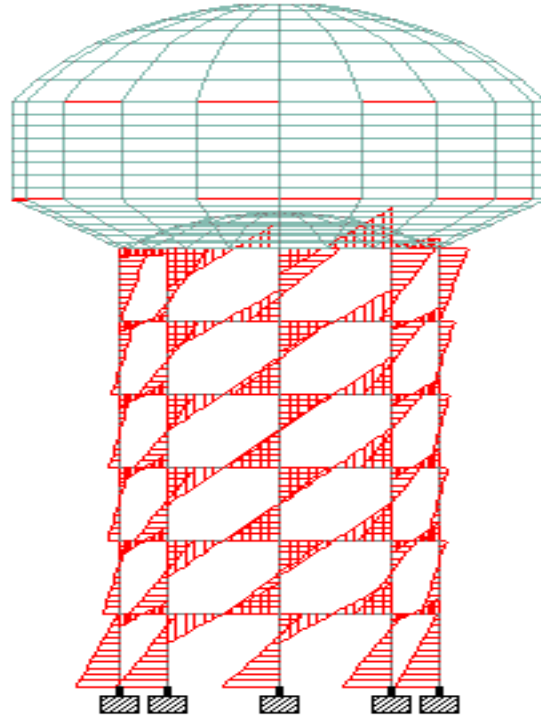


Figure 4.8: BENDING MOMENT DIAGRAM OF WATER TANK

The above figure 4.8 shows the bending moment diagram of the water tank with respect to the loading conditions.

	A	B
1	≤ 0.007653	0.503531
2	0.503531	0.999408
3	0.999408	1.49529
4	1.49529	1.99116
5	1.99116	2.48704
6	2.48704	2.98292
7	2.98292	3.47879
8	3.47879	3.97467
9	3.97467	4.47055
10	4.47055	4.96643
11	4.96643	5.4623
12	5.4623	5.95818
13	5.95818	6.45406
14	6.45406	6.94994
15	6.94994	7.44581
16	7.44581	≥ 7.94169

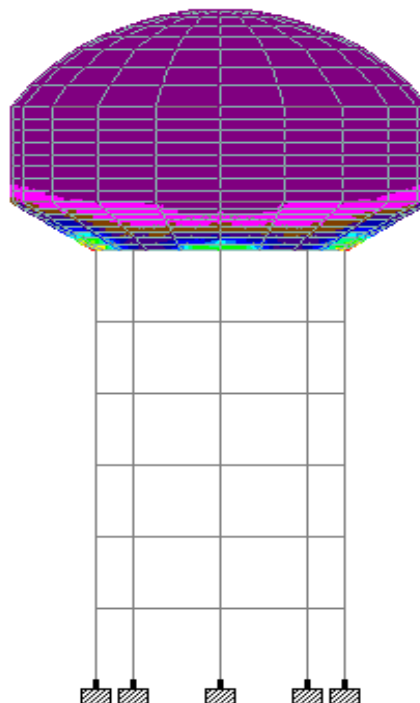


FIGURE 4.9: THE PLATE PRESSURE OF THE WATER TANK AND IT'S VALUE

The above figure 4.9: shows the plate pressure or the pressure applied by the water with respect to the staging. The figure itself denotes the pressure is higher at the bottom dome and the ends of the water tank.

The below figure 4.10 shows the concrete design for slabs and the figure 4.11 shows the design of column and the figure 4.12 shows the design of beams.

Figure 4.10: Slab design

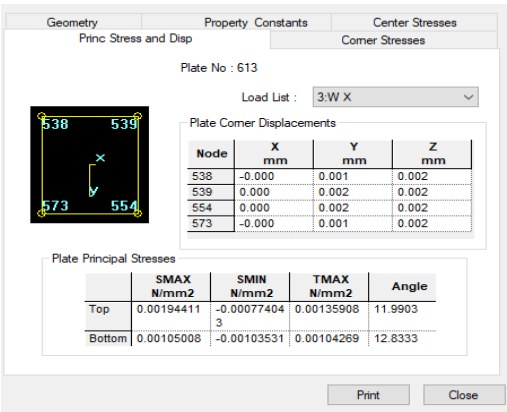


Figure 4.11: Concrete design column

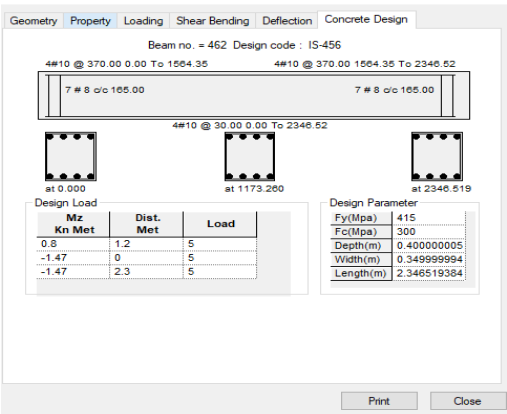
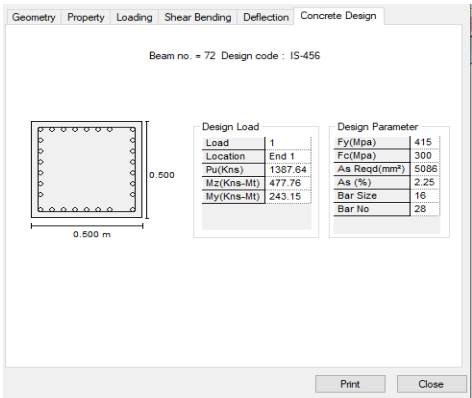


Figure 4.12: Concrete design beams



4.5 STAAD OUTPUT

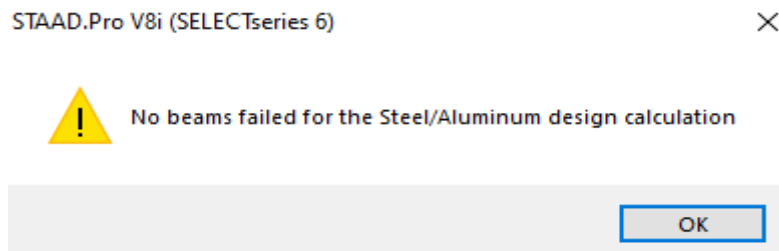


Figure 4.13: beams and columns

LENGTH: 3444.2 mm SIZE: 300.0 mm X 500.0 mm COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	861.0 mm	1722.1 mm	2583.1 mm	3444.2 mm
TOP	1693.72	931.96	288.18	288.18	286.95
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)
BOTTOM	288.18	288.18	288.18	569.99	1315.66
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)

Figure 4.14: Output of bracings from Staad pro

The above figure 4.13 and figure 4.14 shows the output of the design by entering into by specifications in staad pro and checking for all failed beams which gives the final value of the beams and columns.

CHAPTER- 5

PIPING AND ESTIMATION OF THE TANK

5.1 PIPELINE AND STAIRCASE DESIGN

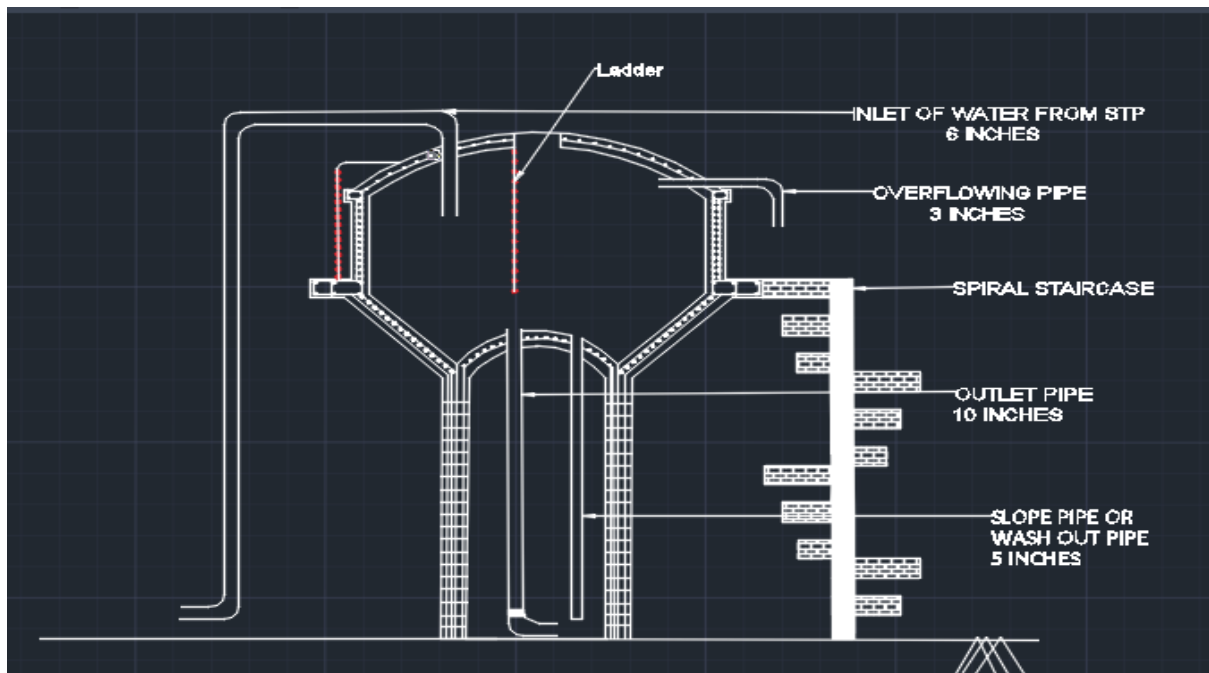


Figure 5.1: Pipeline diagram

The above figure 5.1 shows the pipeline diagram of the water tank and the design of staircase for the tank.

The below figure 5.2 and figure 5.3 shows the design of stair case for the water tank by both AutoCAD and Staad.Pro.

Figure 5.2: Staircase diagram (AutoCAD)

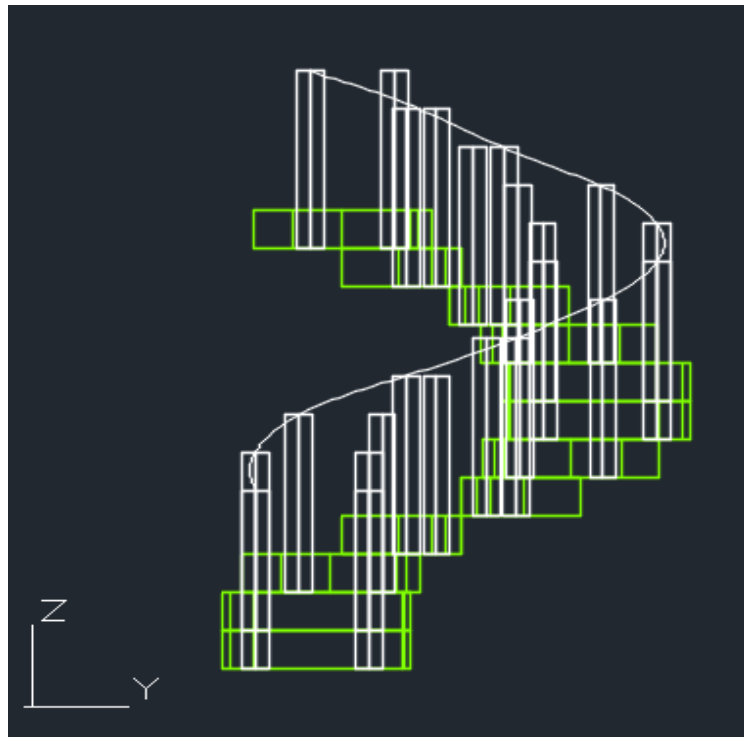
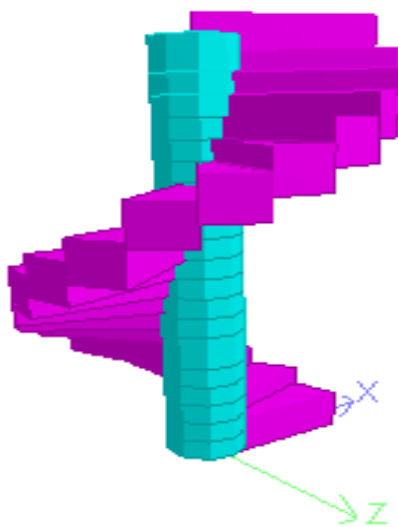


Figure 5.3: 3d-stair case (Staad pro)



Total number of stairs = 120

Riser used in the stairs = 150mm

Thread used in stairs = 300mm

Angle θ = 18°

Pipes used for the water tank are as follows

Inlet pipe = 6 inches pipe (PVC pipes are not recommended)

Outlet pipe = 10 inches pipe (PVC pipes are not recommended)

Overflowing pipe = 3 inches pipe

Washout pipe = 4 inches pipe

Above pipes are the cast iron pipe or GI pipes (Galvanised Iron) are the highly recommended for the water tank because it can withstand pressure which a normal PVC pipes cannot do so every water tank has the GI pipes and cast iron pipes.

5.2 PIPELINE LAYOUT OF WATER TANK

The pipeline layout of water tank is shown in below figure 5.4 and it has been designed for the flow of water through the plan so that the flow of water from the water tank to the other area of the plan has a smooth flow of water and the water staging and pressure acts as drive force so that the water can move through the pipeline according to the plan.



Figure 5.4: water line layout for water tank

5.3 ESTIMATION OF THE TANK

The estimation of water tank is the rough calculation required for the build of the water tank and the below estimation is done by manually for concrete and the estimation for steel is done by staad pro.

The approximation for the design of the Intze water tank for the construction has been shown in figure 9.1 and figure 9.2

Some of the formula used for the estimation for concrete is

- Volume of dome (Hemisphere) = $\frac{2}{3} \times (\pi \times r^3)$
- Volume of conical portion (Frustum) = $\frac{1}{3} \times \pi \times h \times (r_1^2 + r_2^2 + (r_1 r_2))$
- Volume of cylindrical portion = $\pi \times r^2 \times h$
- Volume of rectangle portion = $L \times B \times H$

Staad pro the output files shows the quantity of steel rods or reinforcements required for the structures.

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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 =          101.0 CU.METER

      BAR DIA      WEIGHT
      (in mm)      (in New)
      -----
          8          12249
         10          4603
         12          20784
         16          29530
         20          26939
         25           6335
         32          24747
      -----
    *** TOTAL=          125187

1240. PERFORM ANALYSIS
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Figure 5.5 : Staad pro estimate for steel used for water tank

Sl.no	Description of structures	NOs	Length	Breath	Depth	Quantity	Total Quantity
			M	M	M	M ² /M ³	M ² /M ³
1	Columns	8	0.50	0.50	18	4.5	36
2	Bracings	40	8	0.30	0.5	1.2	48
3	Circular Girder	8	9	0.75	0.90	6.075	48.6
	Tank portion						
4	Bottom Dome	1	4.5	-	1.5	183.61	183.61
5	Conical Portion	1	7.5	4.5	2	230.90	230.90
6	Bottom ring Beam	20	0.95	0.90	0.95	0.81	16.24
7	Cylindrical portion	1	7.5	7.5	4	706.85	706.85
8	Top Ring Beam	20	1.40	0.35	0.40	0.056	1.12
9	Top dome	1	7.5	-	2	866.7	866.7
	TOTAL =						2172.86

Figure 5.6 : Estimation for concrete used for water tank

CHAPTER – 6

CONCLUSION

The storage of water is the process done by the Intze water tank which helps the supply of water through the collage continuously and the water source by the STP (sewage treatment plan) always has the production of purification of water and then the purified water is been raised to the water tank which is staged 18 meter or 60 feet top so that that causes a drive force to drive water to a certain areas. The Intze water tank generally cost efficient because of the consisting of lower dome to reduce the outcome of the horizontal thrust of the tank and hoop tension.

The Intze water tank the diagrams are drawn with the assistance of AutoCAD software and the further analysis such as the design and the structure analysis have been done with the help of Staad.Pro software.

The design of this tank is made with the concrete grade of M30 in which all the liquid retaining structures generally use this grade of concrete.

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