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Design of Overhead Storage Tank Using Staad Pro

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Abstract
Water tanks are very crucial structures for storing large amounts of water for various purposes such as domestic use, industrial use, and irrigation purposes. There are three types of water tanks based on their position with respect to ground level. To reduce the usage of electricity, overhead water tanks are a good option for supplying water with the help of gravity. This project involves the designing of an overhead storage water tank for a specific locality (Pawantara, Raipur) and a comprehensive analysis of it using STAAD Pro, a widely utilized structural analysis and design software. The design method used in STAAD Pro analysis is Limit State Design. The primary objective of this analysis is to evaluate the tank's response to various loads, including dead loads, live loads, wind loads, and seismic forces, adhering to relevant design codes. Additionally, the project includes estimating the cost of the structural members based on the design outputs. The study also emphasizes how the shapes of tanks play a predominant role in stress distribution, overall structural efficiency, and economy.

Keywords: Overhead storage water tank, comprehensive analysis, STAAD Pro, Limit State Design, structural cost estimation
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I. Introduction

Water is a fundamental and necessity for human life. According to the Union Ministry of Water Resources, India's water requirement was 1,100 BCM (billion cubic meters) in 2017 and the ministry estimated that this would increase to 1,447 BCM by 2050. Water is also crucial in the chemical, irrigation, agricultural and industrial sectors. Thus, storing water in large amount is very important for various purposes. Water tanks are containers used to store large amount of liquid. Tanks can be manufactured from RCC or steel. The main objectives to store water in water tanks are: -
1. To provide safe drinkable water after storing for a long time,
2. Also to optimize cost, strength, service life
3. To be stable during exceptional situations such as earthquakes.
4. To keep the water's pH stable and to inhibit microbial growth.

We are going to design and analyze an overhead water tankto serve plenty of water to the families of the locality named Pawantara, Raipur. Overhead tanks are typically lifted from ground level using a series of columns and beams. Elevated water tanks are one of the most effective storing facilities used for domestic or even industrial purposes. This is because no additional energy is required for supplying water because of gravity. The design and analysis of the overhead tank will be achieved by the software named "STAAD PRO". In recent times STAAD Pro software was explored mostly as the software saves time in doing the design with a percentage of accuracy.By using STAAD.Pro, this project provides a comprehensive understanding of the complexities involved in designing overhead storage tanks, allowing engineers to make informed decisions regarding material selection, design optimization, and structural safety. The outcomes of this project can contribute to improving the design and construction practices of overhead storage tanks in various industrial and municipal applications.

II.Methodology

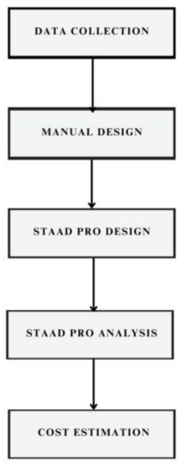


Fig 1Flow chart of the project

2.1 DATA COLLECTED

- SBC of soil = 100 KN/Sq. m
- Seismic zone II
- Capacity of tank = 60KL
- Diameter of tank = 4.9m

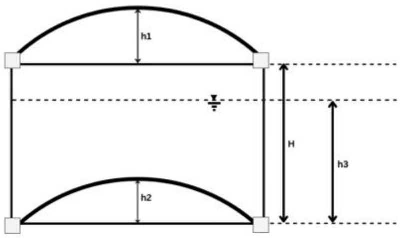
2.2 MANUAL DESIGN

The 60 kL overhead water tank is designed with M30 concrete and Fe415 steel. It has an RCC cylindrical tank with a 1.65m height and 4.9m diameter, supported by 8 circular columns (400mm diameter, 12m height). The top ring beam (200×200mm) and bottom ring beam (500×400mm) ensure stability using limit state method.

2.2.1 GIVEN OR ASSUMED

- SBC of soil = 100 KN/Sq. m
- Seismic zone II
- Staging = 12m
- Capacity of tank = 60KL
- Free board = 150mm [Assume]
- Spherical dome rise(bottom) [h2] = 1.2m [Assume]
- Spherical dome rise(top) [h1]= 1m [Assume]
- Diameter of tank [D]= 4.9m
- Thickness of walls = 100mm [Assume]
- Grade of concrete = M30

2.2.2 HEIGHT OF CYLINDRICAL TANK



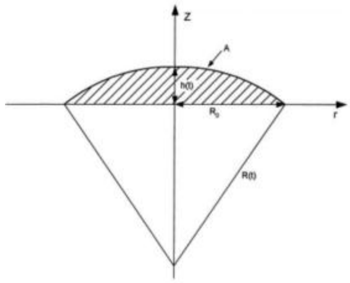


Fig 2 Cross section of the tank Fig 3 Arc formulae

Determining the value of r2 [radius of bottom dome]
$h2 \times (2*r2 - h2) = (D / 2)^2$
$1.2\times (2*r2 - 1.2) = (4.9/ 2)^2$
$r2 = 3.1m$
Determining the value of r1 [radius of Top dome]
$h1 \times (2*r1 - h1) = (D / 2)^2$
$1.5\times (2*r1 - 1.5) = (4.9/ 2)^2$
$r1 = 2.7m$
Volume of cylinder – Volume of bottom dome = Capacity of tank
$[\pi/4 * D^2 * h3] - [\pi * h2^2 * (r2 - h2/ 3)] = 60$
$[\pi/4 * 4.9^2 * h3] - [\pi * 1.2^2 * (3.1 - 1.2/ 3)] = 60$
$h3 \sim 1.5m$
Total height of cylinder = depth of water stored + free board
$H = 1.5m + 0.15m$
$H = 1.65m$

2.2.3 DESIGN OF TOP BEAM
Total Dead load on top dome = Unit weight of RCC * thickness of wall
2.5 * 0.1
2.5KN/m ^{2}
Total live load on top dome = 1.5 KN/m ^{2}
Total load on top dome = 2.5 + 1.5 KN/m ^{2} = 4 KN/m ^{2}
Maximum meridional thrust = $(W\ r1)/ (1+\cos\alpha)$
$4*2.7/(1+\cos 44.4)= 6.2$ KN/m < 6N/mm ^{2}[SAFE]

2.2.4 TOP RING BEAM DESIGN
The top ring beam, located at the base of the tank, provides support to the tank walls and ensures uniform load transfer to the supporting columns. It has a cross-sectional size of 200 mm × 200 mm and is constructed using M30 grade concrete with Fe415 grade steel. The beam is designed to resist bending moments and shear forces effectively.

2.2.5 COLUMN DESIGN
The overhead water tank of 60 kL capacity is supported by a staging structure consisting of 8 columns that are circular in shape. Each column has a cross-sectional dimension of 400mm (diameter) and staging height of 12 meters from the foundation to the tank base. The columns are designed using M30 grade concrete for durability and strength, along with Fe415grade steel for reinforcement. The axial load on each column is carefully considered to ensure structural stability. The longitudinal reinforcement consists of 12 mm diameter bars, with 8number of bars evenly spaced to provide adequate strength. The column design ensures stability against vertical loads, lateral forces, and seismic effects as per IS code provisions.

2.2.5 BOTTOM RING DESIGN
The bottom ring beam, positioned near the base of the staging columns, acts as a bracing element to distribute the load evenly and enhance lateral stability. It has a cross-sectional dimension of 400 mm × 500 mm, constructed with M30 grade concrete and Fe415 grade steel.
Both the top and bottom ring beams play a crucial role in resisting horizontal and vertical forces, ensuring the overall stability and durability of the overhead tank structure.

2.3 STAAD PRO DESIGN

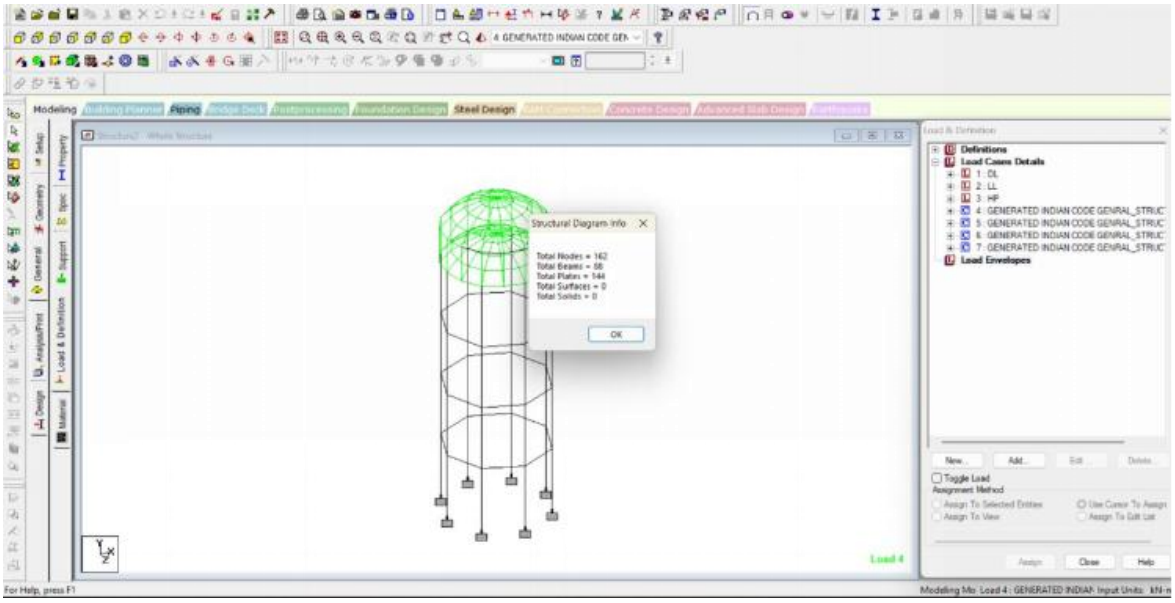


Fig 4 Information About The Designed Model Of Tank In Staad Pro Along With Consideration Of Different Loads

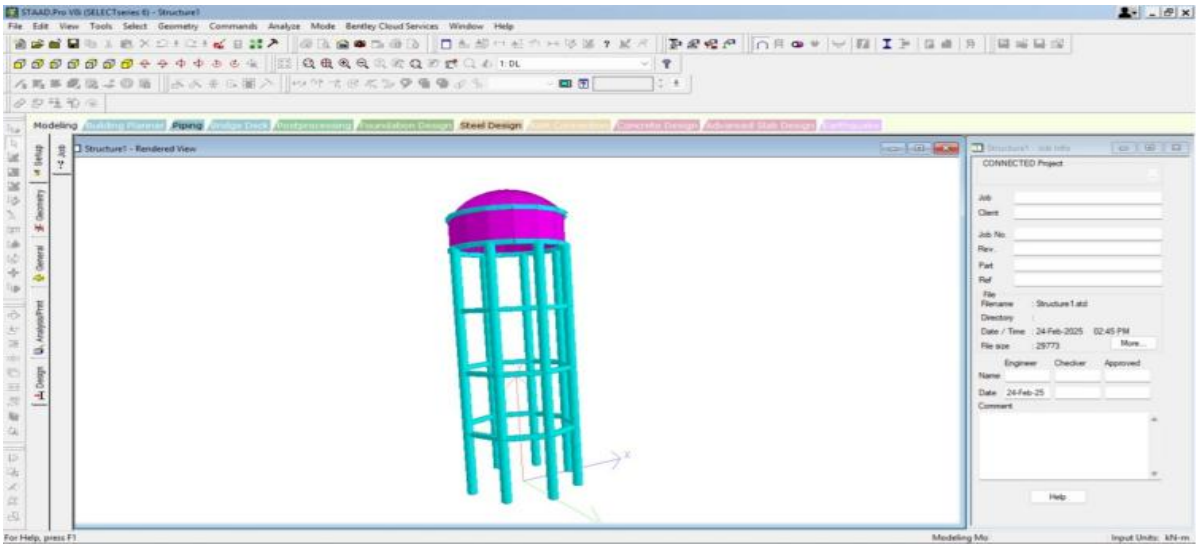
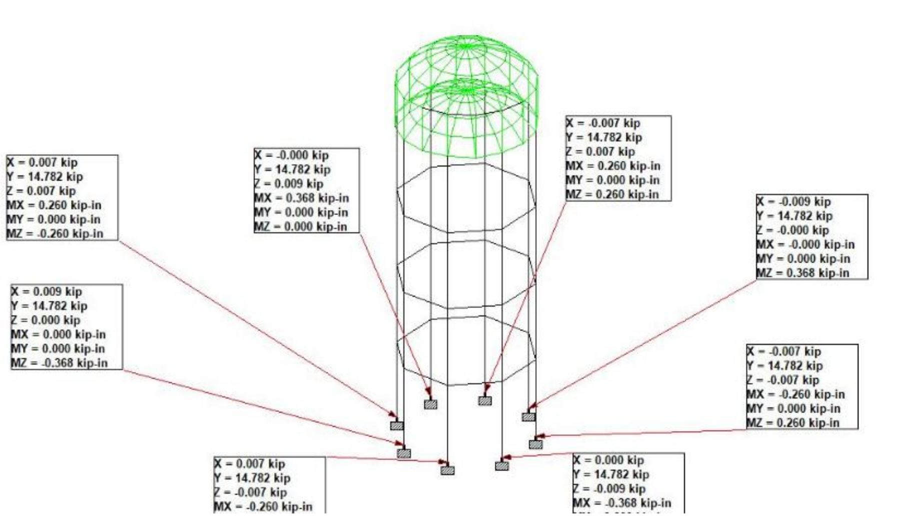
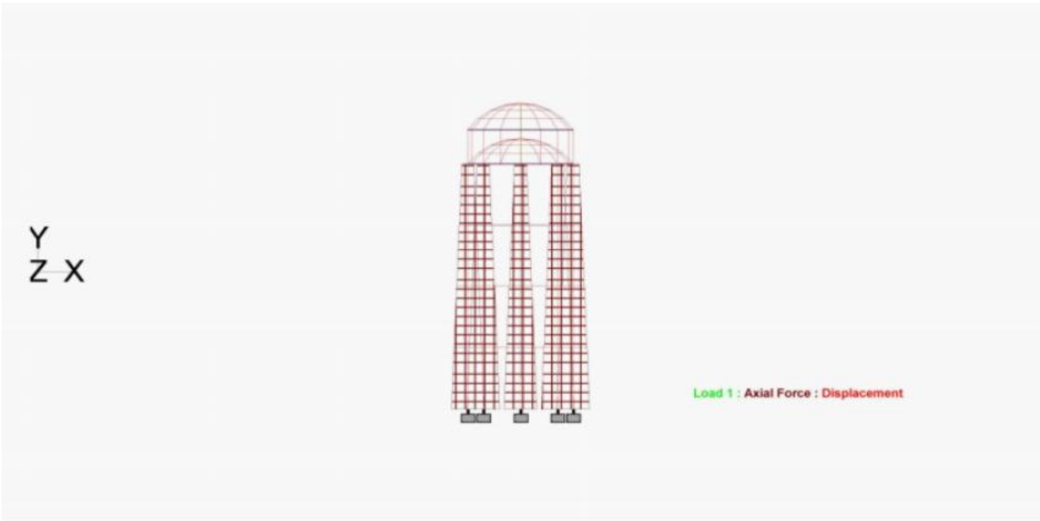


Fig 53D Rendered View of The Tank

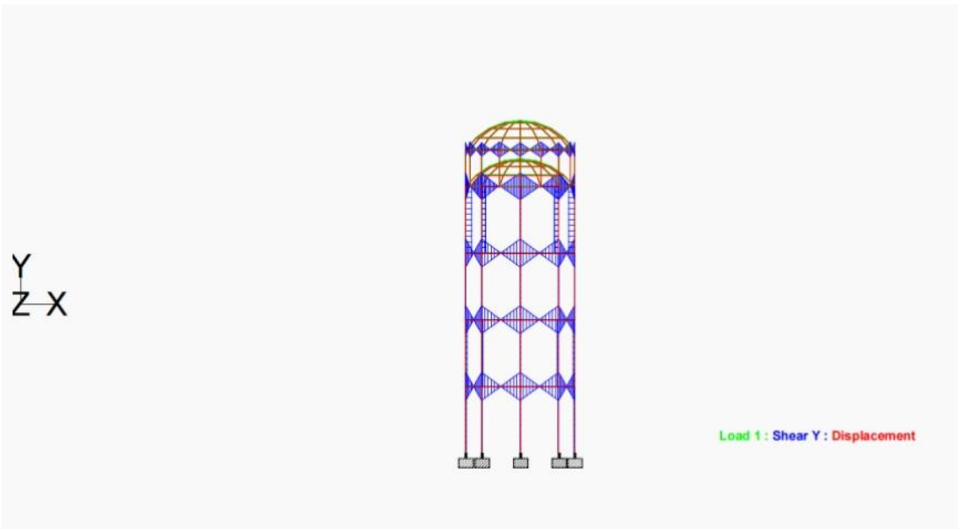
2.4 STAAD PRO ANALYSIS



Loads On Supports



Effect Of Axial Force



Effect Of Shear Force

2.5 COST ESTIMATION

Concrete Calculations

Concrete Volume = 18.000 m^3
Dry Volume = 1.54m^2

Calculate Cement, Sand, Coarse aggregate and Admixture
Selected Concrete mix design is M30
Mix Ratio for M30 is 1.0:0.75:1.5

Calculate Concrete parts by using the formula:-
Concrete parts = Cement part + Sand part + Coarse Aggregate part + Admixture part
Concrete parts = 1.0 +0.75 +1.5 +0.01
=3.26

Cement Quantity

Calculate Cement Quantity by using form
Cement Quantity = (Cement part / Concrete part) * Concrete Volume * Dry Volume.

Cement Quantity = (1.0/8.26)×18.000X)×1.5V = 8.508m^2
Density of Cement = 1440 kg/m
Weight of Cement = 8.503 ×1440 = 122 44.417
Weight of Cement Bag's = 50 kg
Total Bags= 12244.417/50 = 244.888 Cement Bags-245 Cement Bags

Sand Quantity

Calculate Sand Quantity by using formula
Sand Quantity = (10.75/9.20)×18.000×1.54 = 6.837 m^3

Aggregate Quantity

Calculate Aggregate Quantity by using formula
Aggregate Quantity= (1.5/3.26)×18.000×1.54= 12.755m^3

Admixture Quantity

Calculate Admixture Quantity by using formula.
Admixture Quantity = Cement Quantity ×Admixture.
Admixture Quantity = 12244.417×0.01 = 122. 44g

Water Quantity

Calculate water Quantity by using formula
Water Quantity = Cement Volume x Water Cement Ratio
Water Quantity = 8.503X0.45 = 3.826m^2
Unit weight of water= 1000 L / m^2
Required Amount of water = 3.826 X 1000 = 3826.380 L

ABSTRACT ESTIMATE OF STRUCTURAL MEMBERS

Description Of Item	Qty	Unit	Rate	Per	Amount
Cement	245	Bags	360	Bags	88200
Sand	6.38	m^3	1600	m^3	10208

Aggregate	12.76	m^3	20200	m^3	28072
Steel	1136	Kg	70	Kg	79520
				TOTAL = 206000 /-	

→ Add 5%. for Contingency and work-charge establishment.
= 206000 X 5/100
= 10300

Total Cost = 206000 + 10300
= **216300 Rs**

III. Conclusion

i. By Using STADD Pro., analysis and design of water storage overhead tank is easier and quick process than manual process.

ii. The beam (400 mm × 500 mm) and column (Dia-400mm & Height-12 m) can be safely used in the structure.

iii. The structure is safe in shear bending and deflection.

iv. There is no hazardous effect on the structure due to wind load and seismic load on the structure.

v. To know the behavior of the structure by applying various loads like dead load, live load, wind load and seismic load by using staad.pro. And also find out the Shear forces, displacement, bending and reactions of structure.

vi. By using STAAD Pro, we performed dynamic analysis. So that, the results obtained in STAAD Pro is more effective as compared to analysis and design performed by theoretical method.

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