Design of Water Tank for the Town of Population 50000 and Analysis by-Staad Pro

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ABSTARCT-

Storage reservoirs and overhead tanks are commonly employed for storing water, liquid, petroleum, and other similar liquids, and their structural analysis is similar regardless of the product being stored. The design of all tanks, whether for water, liquid petroleum, or petroleum products, aims to create crack-free structures that prevent leakage. This paper gives a broad review of the theory behind the design of liquid retaining structures, include of circular water tanks with flexible and rigid bases, as well as rectangular underground water tanks, by use of the working stress method. In addition to theoretical explanations, this report also includes computer using Staad Pro for analyzing and designing circular water tanks with flexible and rigid bases, as well as rectangular underground water tanks. To validate the accuracy of the programs, the results obtained from the computer subroutines are compared with manual calculations from a reference source such as a Concrete Structure book

Keywords- Water tank, Design, STAAD Pro, Structural analysis, Structural stability, Seismic analysis, Safety regulations

1. INTRODUCTION

Welcome to the world of engineering! As the town's population grows, the need for essential infrastructure, such as water supply, becomes increasingly important. One critical aspect of water supply infrastructure is the design of water tanks. In this project, we will be using the powerful engineering software, STAAD Pro, to design a water tank for a town with a population of 50,000.

Designing a water tank involves various considerations, including structural stability, capacity, durability, and functionality. The tank must be designed to withstand the weight of the water it holds, as well as potential external loads such as wind and seismic forces. The water tank must also comply with relevant building codes and regulations to ensure its safety and reliability.

By utilizing STAAD Pro, a widely used and sophisticated software for structural analysis and design, we can efficiently model and analyze the behavior of the water tank under different loads and conditions. STAAD Pro offers advanced features for modeling, analysis, and design of complex structures, making it a powerful tool for designing water tanks with precision and accuracy.

With the goal of providing a reliable and sustainable water supply to the growing population of the town, the design of the water tank using STAAD Pro will involve a thorough analysis of various factors to ensure its stability, efficiency, and compliance with industry standards. Through this project, we aim to create a water tank design that meets the needs of the town's population and contributes to the overall well-being and development of the community.

2. LITURATURE REVIEW

1. San Jasim Mohammed (2016)

In their study he concluded that an optimization method was applied to the structural design of concrete water tanks, both rectangular and circular, taking into consideration the total cost of the tank as an objective function. The design variables included tank capacity, width, and length for rectangular tanks, and water depth for circular tanks, as well as unit weight of water and tank floor slab thickness. The researchers developed a computer program to solve numerical examples using the Indian IS: 456-2000 Code equations. The results indicated that the tank capacity minimizes the total cost for rectangular tanks, but maximizes it for circular tanks. Similarly, the tank floor slab thickness minimizes the total cost for both types of tanks. The unit weight of water in the tank minimizes the total cost for circular tanks, but maximizes it for rectangular tanks.

2. Rajkumar, Shivaraj, and Prof. Mangalgi (2017)

in their research paper titled "Response-Spectrum Study Of High-Rised Intze and Circular Water Tanks," found that the total base shear in full tank condition was higher compared to empty tank and half-filled conditions in both seismic zones II and V for both Intze and circular tanks, indicating that the design of elevated water tanks is primarily governed by the full tank condition due to its complexity and involving various mathematical calculations and time-consuming processes, for which Staad pro provides useful parameters.

3. Issar Kapadia, Nilkunj Patel, Nilesh Dholiya, and Purav Patel (2017)

The research conducted by title " Analysis and Design of INTZE Type Overhead Water Tank under the Hydrostatic Pressure as Per IS: 3370 & IS: 456 -2000 by Using STAAD Pro Software," utilized STAAD Pro Software to arrive at the conclusion that an increase in moment occurs with an increase in height of the structure, and the use of fixed joints at the base results in a significant reduction in base settlement. Additionally, the researchers found that the INTZE type water tank, with its inclined staging, performs better compared to a straight tank, making it a simpler yet effective design choice.

3. METHODOLOGY

3.1 Design Considerations for Concrete in Water Retaining Structures

To ensure impermeability, a dense concrete mix with a high quality is required for water retaining structures. Concrete mixtures weaker than M20 should not be used, and the minimum quantity of cement in the mix should be at least 30 kN/m3. The design of the concrete mix should result in a sufficiently impervious concrete, achieved through efficient compaction, preferably by vibration.

The design of liquid retaining structures differs from ordinary RCC structures as it requires consideration of cracking and tensile stresses. The tensile resistance of concrete in bending is ignored, and the tensile stress on the liquid retaining face should not exceed the permissible tensile strength of concrete Stresses caused by temperature differences between inside and outside of the reservoir should be taken into account for structures storing hot liquids, using coefficients of expansion and shrinkage for temperature changes as specified.

3.2 Joints in liquid retaining structures

I. Movement Joints

There are Three types of Movement Joints

a. Contraction Joints

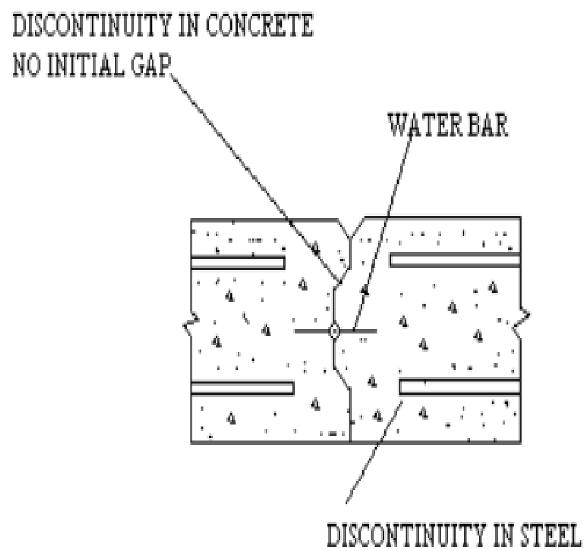

Fig 1. Contraction Joint

b. Expansion Joints

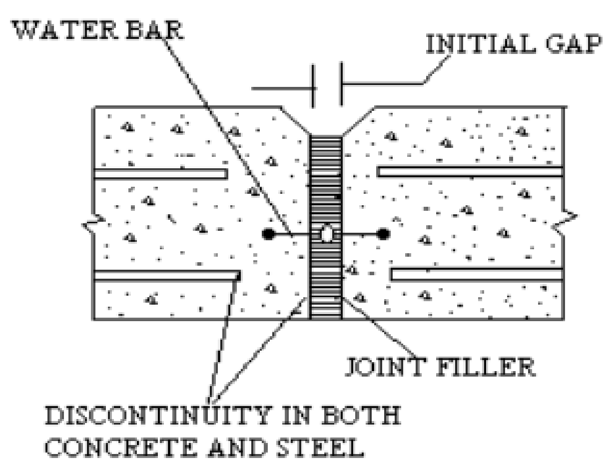

Fig 2. Expansion Joint

c. Sliding Joint

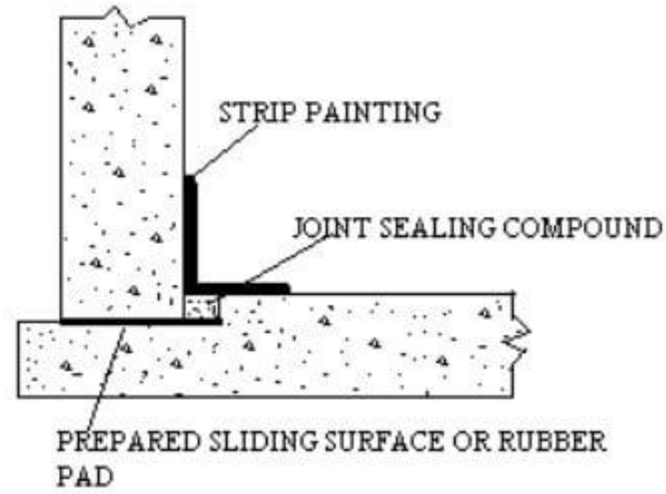

Fig 3. Sliding Joint

II. Contraction Joints

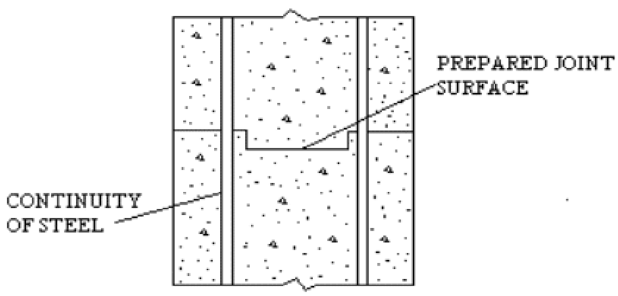

Fig 4. Contraction Joint

III. Temporary Joints

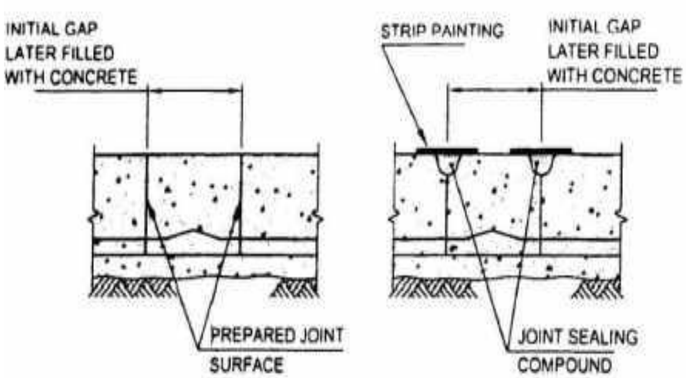

Fig 5. Temporary Joint

3.3. Flexible Base Circular Water Tank

Circular water tanks with flexible bases are commonly used for larger capacities due to the hydrostatic pressure exerted on the tank walls. Rectangular tanks are typically utilized for smaller capacities, while circular tanks with flexible bases are preferred for larger capacities. The design of circular water tanks with flexible bases takes into consideration the reduction of hoop tension towards the top, resulting in minimized reinforcement requirements at the upper portion. A flexible base circular water tank is a type of water storage tank that is designed with a flexible or deformable base. The base of the tank is made of a material that can flex or bend in response to changes in the ground or foundation, such as settlement or soil movements. This design allows the tank to adapt to uneven or shifting ground conditions without causing damage to the tank structure. The flexible base of the circular water tank typically consists of a combination of materials that provide stability, strength, and flexibility. This can include materials such as reinforced concrete, steel, or high-density polyethylene (HDPE) liners. The flexibility of the base allows it to absorb and distribute stresses caused by ground movements, preventing the tank from cracking or failing.

3.4 Rigid Base Circular Water Tank

The tank is designed to be installed on a stable and solid base, such as a concrete foundation, to provide stability and prevent settling or movement of the tank. Installation of a rigid base circular water tank typically requires professional expertise and adherence to local building codes and regulations. Rigid base circular water tanks are commonly used in a wide range of applications, including residential, commercial, agricultural, and industrial settings, where a reliable and durable water storage solution is needed. Proper design, construction, and maintenance are essential to ensure the safety, reliability, and longevity of these tanks. Consulting with a qualified engineer or water tank professional is recommended for proper selection, design, and installation of a rigid base circular water tank based on specific requirements and local regulations.

3.5 Rectangular Under Ground Water Tank

Underground tanks, such as purification tanks, Imhoff tanks, septic tanks, and gas holders, are constructed below the ground surface, with design principles similar to tanks subjected to internal water pressure and external earth pressure. The base of these tanks bears the weight of water and soil pressure, and they may also be covered at the top. In cases where there is a potential for the water table to rise and saturate the soil, the earth pressure exerted by saturated soil should be taken into account in the design of these tanks.

For underground tanks with a length-to-breadth ratio greater than 2, the long walls are designed as cantilevers, while the top portion of the short walls are designed as slabs supported by the long walls. The bottom one meter of the short walls is designed as a cantilever slab.

The design of underground tanks, such as purification tanks, Imhoff tanks, septic tanks, and gas holders, takes into consideration factors such as internal water pressure, external earth pressure, potential rise of water table, and the length-to-breadth ratio of the tank.

Underground tanks, including purification tanks, Imhoff tanks, septic tanks, and gas holders, are designed to withstand internal water pressure, outside earth pressure, and the possibility of saturated soil due to rising water table. The design includes cantilever walls for tanks with a length-to-breadth ratio greater than 2, and slab-supported walls for the top portion of short walls.

3.6 Software : STAAD-Pro

Staad Pro software has been utilized for the project's design and analysis requirements, employing fundamental concepts of loading, analysis, and adherence to IS code standards. Different scenarios have been addressed using Staad Pro, applying basic techniques of loading, analysis, and compliance with IS code guidelines, which may serve as a valuable reference for future problem-solving. Staad Pro boasts an advanced user interface, visualization tools, and powerful analysis and design engines with cutting-edge finite element and dynamic analysis capabilities, making it the go-to choice for professionals engaged in steel, concrete, timber, aluminium, and cold-formed steel design for various structures. Staad Pro has been employed for tasks ranging from model generation, analysis, and design to visualization and result verification, catering to a wide range of applications such as low and high-rise buildings, culverts, petrochemical plants, tunnels, bridges, piles, and more.

Staad Pro's state-of-the-art features and capabilities make it a preferred software for the design and analysis of diverse structures, providing a comprehensive solution for professionals involved in projects involving steel, concrete, timber, aluminium, and cold-formed steel design. Staad Pro has been utilized to effectively address typical design and analysis challenges, leveraging its robust features, including advanced finite element and dynamic analysis capabilities, in compliance with IS code guidelines. Staad Pro has proven to be a reliable and efficient tool for the design and analysis of a wide range of structures, providing comprehensive solutions for professionals involved in the construction of low and high-rise structures, culverts, towers, tunnels, bridges, piles, and more.

5. DESIGN AND ANALYSIS

- **Design of Circular Tank with Flexible Base (resting on ground)**

Given:

Capacity of tank : 500000 lit

Grade of Concrete : M30

Grade of Steel : Fe415

Step 1: Dimension of Tank

height of Tank = 4.5m

free Board = 0.2m

depth of water in tank = 4.3m

As,

Volume = capacity

$\pi/4 \times d^2 \times h = 500000/1000$

d = 12.2m

Step 2: Design of Section

$\gamma_w = 9.8$ KN/m²

Maximum hoop tension on base of tank(T) = $\gamma_w \times h \times d/2$

T = 269.01 KN/m

$Ast_{req} = T / \sigma_{st}$

As per IS:3370 ,

for Fe 415 $\sigma_{st} = 150$ N/mm²

Ast_{req} = 1793.4 mm²

Hence provide hoops of 20mm ϕ bars @ 160mm c/c

Actual Ast = 1963.43 mm²

Here 1963.43 > 1793.4

Hence OK

Step 3: Thickness of Wall

As per IS:3370,

Permissible direct tensile stress in concrete = σ_{ct} = T / 1000t+ (m-1) x Ast

for M30, σ_{ct} = 1.5 N/mm^2

m = 280 / 3σ_{cbc} [M30, σ_{cbc} = 10]

m = 9.33

Hence, t = 163 mm

Step 4: Verticle Reinforcement or Distribution Steel

for t = 163 mm, percentage of steel (Pt) = 0.28 %

Ast = Pt/100 x B x D

= 456.4 mm^2

Hence provide 10mm ϕ bars @ 170 mm c/c

Step 5: Design of Base Slab

Provide a thickness of 150 mm

0.3 % of gross area

Ast = 0.3/100 x 1000 x 150

= 450 mm^2

Provide half of reinforcement in each direction

= 225 mm^2

Hence provide 8mm ϕ bars @ 200 mm c/c

Provide 75mm of thick layer of lean concrete below bottom of slab

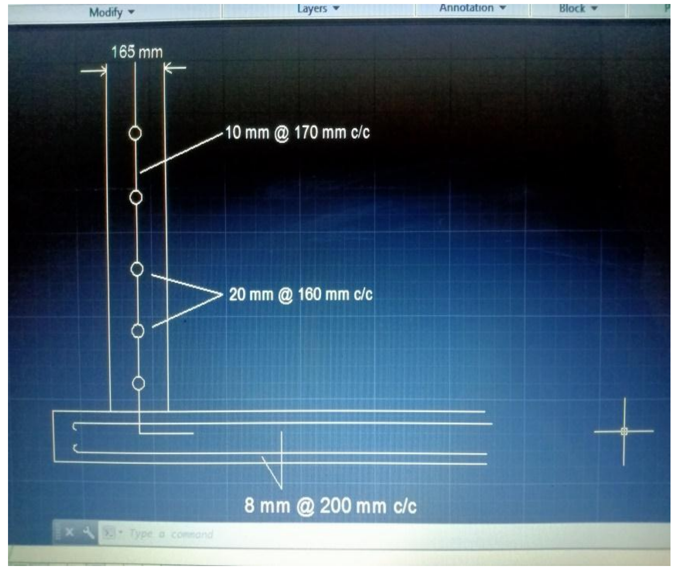

Fig 6. Reinforcement Details in Flexible Base

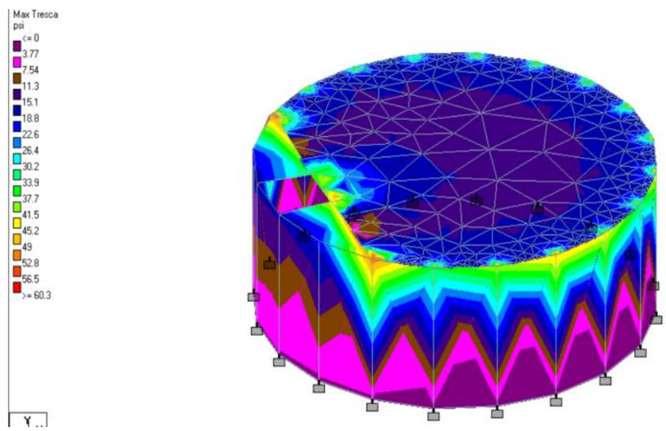

Fig 7. Pressure Distribution on Circular Tank

<u>In this way, similarly circular rigid base water tank and rectangular underground water tank was design according to IS:3370 and analysis by STAAD Pro software as shown in fig. 8,9,10 &11</u>

- **Rigid Base Circular Water Tank**

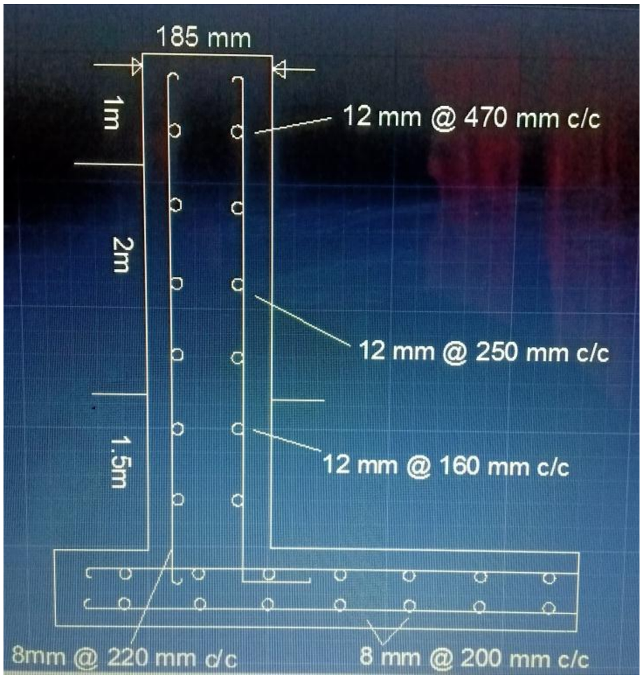

Fig 8. Reinforcement Details in Rigid Base

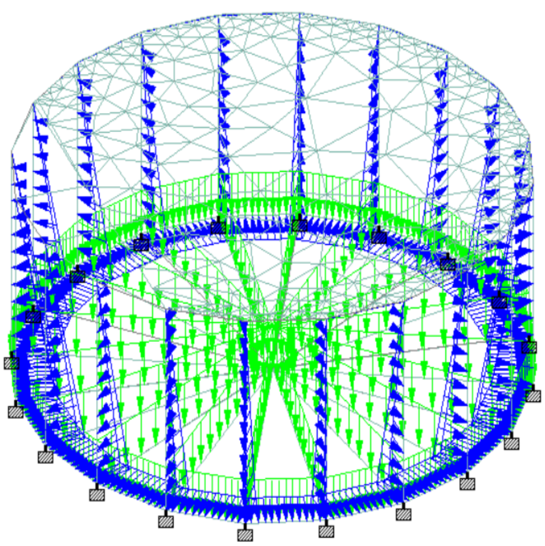

Fig 9. Load Distribution on Circular Tank

- **Rectangular Underground Water Tank**

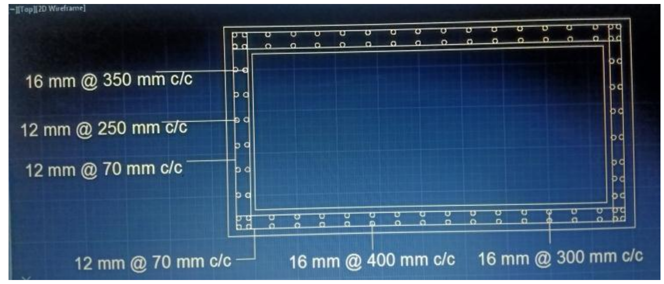

Fig 10. Reinforcement Details of Rectangular Tank

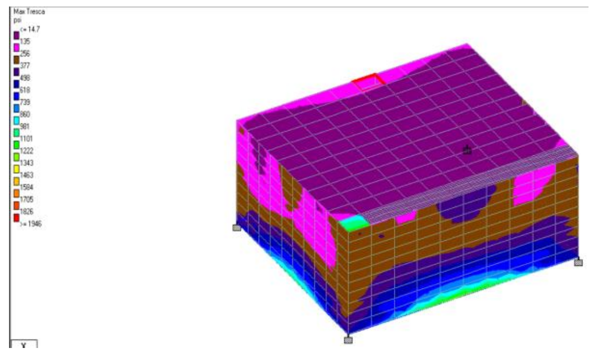

Fig 11. Pressure Distribution on Rectangular Tank

6. RESULT

Table 1. Design Details of Water Tank

	Flexible Base Circular Water Tank	Rigid Base Circular Water Tank	Rectangular Underground Water Tank
Dimension (m)	Dia = 12.2	Dia = 12.2	L = 12 , B = 10
Height (m)	4.5	4.5	4.5
Thickness of wall (mm)	165	185	500
Thickness of roof (mm)	100	100	200
Thickness of base (mm)	150	150	550
Bar size (mm) Max Min	 20 10	 12 08	 16 10
Main Reinforcement (mm^2)	1964	2823	Long wall-1750 Short wall- 921
Distribution Steel (mm^2)	460	470	Long wall-1500 Short wall- 1500

7. CONCLUSION

The storage of water in tanks, whether rectangular or circular, serves various purposes such as drinking, washing, swimming for exercise and enjoyment, and sedimentation of The program provides design values for water tanks, which may differ slightly from manual calculations but offer the least value for design. Designers should not provide values lower than those obtained from the program to ensure safety. sewage, which are gaining increasing importance in modern life.

The design of water tanks, especially underground tanks, can be a tedious and time-consuming process involving complex mathematical formulas and calculations, which can be simplified with the use of a program

In theoretical calculations, designers often add extra values to the obtained results for a safer approach. However, the program's design values are reliable and can be used without the need for additional adjustments.

8. REFERENCES

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