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A Review of Analysis of Underground Water Tanks Considering Different Conditions

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Abstract- Water tanks and reservoirs are essential storage facilities for liquids such as water, petroleum, or chemicals. Water tanks play a crucial role in meeting daily requirements, whether for household or commercial use. This project involves an analysis aimed at designing rectangular and circular underground tanks that maintain ambient temperature and provide optimal height for efficient water pumping to elevated tanks. Given the subterranean nature of these tanks, considerations include lateral earth pressure and water pressure in accordance with IS code standards. Underground water tanks are employed for storing various liquids (e.g., oil, water, gas) and are subject to internal water pressure as well as external earth pressure. The tank foundations must withstand internal water pressure and soil reactions from below, typically being covered at the top. This paper reviews several articles pertaining to the structural aspects of water tanks and reservoirs.

Keywords-Water tank, Seismic load, Hydraulic load, Pressure, Force

I. INTRODUCTION

Expressive constructions are prevalent in hilly areas due to the scarcity of flat ground. Consequently, mountainous regions significantly influence building styles, materials, and construction methods, resulting in distinct structures. Due to the sloping terrain, buildings in such areas often step back towards the hill slope and may have setbacks simultaneously. These structures exhibit high irregularity and asymmetry due to variations in mass and stiffness distributions along different vertical axes at each floor level. Additionally, construction in seismic-prone regions experiences heightened shear forces and torsion compared to typical constructions. Certain regions, such as the northeast area of India, are particularly susceptible to earthquakes. Common construction materials in hilly areas include clay, brick, stone masonry, dressed stone masonry, timber-reinforced concrete, bamboo, etc., sourced locally. The monetary-driven growth and rapid urbanisation in hilly areas have accelerated real estate development.

Table 1. Types of RCC water tanks based on their location and shapes

Location-based water tank	Shape-Based water tank
Underground tanks	Rectangular tank
Tank resting on grounds.	Circular tank
Overhead tanks	Spherical tank
	Intze tank
	Circular tank with conical bottom

II. REINFORCED CONCRETE WATER TANKS

Reinforced concrete water tanks are constructed to store water. The design of these tanks is based on IS 3370:2009 (Parts I - IV). The design varies depending on the location of the tanks, whether above ground, on-ground, or underground. Tanks can be constructed in various shapes, with circular and rectangular shapes being the most common.

Figure 1. RCC water tank on earth's surface

Figure 2. Underground Water Tank

Figure 3. Elevated RCC Water Tank

They can be made of reinforced concrete or steel. Elevated or raised tanks are typically supported above rooftops by columns. Conversely, underground tanks are laid on foundations. Based on the water tank location and their shapes, they are classified as shown in Table 1.

III. LITERATURE REVIEW

Suraj P. Shinde (2018) conducted a comparative analysis of computer-aided design techniques for underground water tanks. The study compared manual design methods using IS code standards with design results obtained from STAAD-PRO and SAP software. Reinforcement comparisons were made, and optimised designs were determined. The research involved the design of a liquid-retaining structure (rectangular water tank) with a capacity ranging from 100,000 to 1,000,000 litres using computer-aided analysis. The deflection shape and axial forces of the tank under various conditions were analysed. Programs were developed to design water tanks with flexible and rigid bases, as well as underground tanks, to simplify complex calculations. The comparison between IS code methods and software design results aimed to identify governing loads and provide a comprehensive literature review on underground water tanks. The study also presented criteria for base deflection, shell stresses, and joint reactions of underground water tank structures, considering dynamic loading conditions with empty and full water levels. Suraj Tripathi et al. (2020) conducted a seismic investigation of an underground water tank with a built-up reinforced concrete structure. The construction followed IS code provisions to mitigate the effects of seismic waves. Time-history analysis was performed using detailed finite element simulations of the underground water tank with SAP 2000 software for varying seismic intensities. The study assessed the tank's behaviour under seismic forces in empty and full conditions. The research focused on a rectangular-shaped underground water tank with an 80,000-liter capacity and dimensions of 6m x 4m x 3.5m. IS:456 2000 and IS:1893 2002 codes were used for structural and seismic analysis, respectively.

The study concluded that time-history analysis was crucial for ensuring seismic safety and designing structurally sound underground water tanks. Komal K. Wagh et al. (2021) presented the design and analysis of a rectangular underground water tank using STAAD Pro software. The study highlighted the unique loadings faced by underground water tanks, primarily horizontal or lateral loads due to earth and water pressure. The analysis and design followed standard specifications outlined in IS-456:2000 & SP-16, utilising the LIMIT STATE method. Unless specified otherwise, the materials used were M20 grade concrete and Fe 415 steel. The conclusion indicated that STAAD Pro provided satisfactory results compared to manual design methods. Using STAAD Pro software resulted in a more efficient design and analysis process, significantly saving time and reducing steel usage. A. C. Chougule et al. (2017) conducted a parametric study on the seismic response of underground water tanks, considering factors such as the spring-mass model, time period, seismic coefficient, base shear, and hydrodynamic pressure. The study found that the distribution of seismic forces varied with the depth-to-diameter ratio of the tank. The base shear, bending moment, and maximum hydrodynamic pressure for round tanks increased with increasing depth-to-diameter ratio. Similarly, these parameters increased gradually for rectangular tanks up to a certain depth-to-length ratio before decreasing. The study emphasised the importance of considering seismic effects in designing underground water tanks to ensure structural integrity and safety. Anshuman Nimade et al. (2018) developed a finite element model of an underground water tank using STAAD.Pro software to analyse its behaviour under different length-to-breadth ratios. The study compared node displacement and stress patterns for various ratios, considering the base pressure and plate moments under empty and full water conditions. The research aimed to provide insights into optimising the design of underground water tanks to enhance their structural performance and stability.

IV. RESEARCH FINDINGS

The analysis of computer-aided design techniques for underground water tanks conducted by Suraj P. Shinde (2018) revealed that manual design methods and software design results obtained from STAAD-PRO and SAP software showed nearly similar deflection shapes and axial forces. The study emphasised computer-aided analysis's importance in simplifying complex calculations and optimising designs. Suraj Tripathi et al. (2020) investigated the seismic behaviour of underground water tanks. They concluded that time-history analysis using SAP 2000 software was crucial for ensuring seismic safety. Komal K. Wagh et al. (2021) demonstrated that STAAD Pro software provided satisfactory results compared to manual design methods, resulting in significant time savings and reduced steel usage. A. C. Chougule et al. (2017) conducted a parametric study on seismic response, finding that seismic forces varied with the tank's depth-to-diameter ratio. They emphasised the importance of considering seismic effects in designing underground water tanks. Anshuman Nimade et al. (2018) developed a finite element model to analyse the behaviour of underground water tanks under different length-to-breadth ratios, providing insights for optimising tank designs. These findings underscore the significance of computer-aided analysis in designing structurally sound underground water tanks and highlight the importance of considering seismic effects for ensuring safety and stability.

IV. CONCLUSION

In conclusion, the reviewed research provides valuable insights into the design and analysis of water tanks, particularly focusing on underground tanks. While the studies have contributed significantly to understanding various aspects of water tank design and behaviour, there are notable gaps and opportunities for further investigation. Firstly, while some authors have analysed elevated water tanks, there's a lack of detailed exploration into the effects of soil pressure on underground tanks. Understanding how soil pressure impacts the structural integrity of underground tanks is essential for ensuring their stability and longevity. Secondly, while several studies have utilised software for analysis, there's room for further exploration into detailed modelling, particularly regarding hydraulic loading and lateral load effects on the structure. Investigating these factors comprehensively provides a more accurate understanding of the behaviour of underground water tanks under various loading conditions. Overall, the research reviewed here underscores the importance of continued exploration and refinement in the design and analysis of water tanks, particularly in addressing the specific challenges and considerations associated with underground structures. Future research can contribute to developing more efficient, resilient, and sustainable water storage solutions by addressing the identified gaps and building upon the existing knowledge base.

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