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Design of Water Tank for the Town Population 40000 Souls - A Review

Ms. Pooja Kamthe[1], Prof. Nakul Shenode[2]
[1]*Research Scholar,* [2]*Assistant Professor, Civil Engineering Department, Swaminarayan Siddhanta Institute of Technology*

Abstract: ***Water storage is a crucial aspect of any urban infrastructure to ensure a sustainable and adequate water supply for growing populations. This review paper discusses the design considerations, structural requirements, and hydraulic principles involved in the construction of a water tank suitable for a town population of 40,000 souls. Various types of water tanks, including overhead, underground, and ground-level tanks, are reviewed, along with their advantages and limitations. The paper also highlights the latest design standards, material choices, and structural safety parameters in compliance with IS codes. A comparative analysis of RCC and steel tanks, including cost estimation, maintenance, and durability, is also presented. The review aims to provide a comprehensive understanding of the fundamental principles governing the design of water storage systems, thereby assisting engineers in optimizing their designs for efficiency and sustainability.***
Keywords: Water Tank Design, Population Demand, Hydraulic Analysis, Structural Stability, RCC Water Tank, Steel Water Tank, IS Codes, Sustainable Water Storage

I. INTRODUCTION

Water storage is a critical component for providing reliable access to clean water for a community. The demand for potable water in any town is influenced by its population size, the water usage per capita, and the desired level of service. This project will focus on designing a water tank that can store an adequate amount of water for a town with a population of 40,000 individuals. Using STAAD Pro software, a modern, widely-used tool for structural analysis and design, we will model and analyze the tank's structural integrity under various loading conditions. Water supply infrastructure is a vital component of urban development. A well-designed water tank ensures an uninterrupted water supply while maintaining adequate pressure within the distribution system. The design of water tanks depends on several factors, including population growth, per capita demand, fire demand, and future expansion plans. This paper reviews the key design principles and selection criteria for different types of water tanks suitable for a town with a population of 40,000.

A. STAAD PRO

STAAD or (STAAD.Pro) is a structural analysis and design software application originally developed by Research Engineers International in 1997. In late 2005, Research Engineers International was bought by Bentley Systems. STAAD.Pro is one of the most widely used structural analysis and design software products worldwide. It supports over 90 international steel, concrete, timber & aluminium design codes. It can make use of various forms of analysis from the traditional static analysis to more recent analysis methods like p-delta analysis, geometric non-linear analysis, Pushover analysis (Static-Non Linear Analysis) or a buckling analysis. It can also make use of various forms of dynamic analysis methods from time history analysis to response spectrum analysis. The response spectrum analysis feature is supported for both user defined spectra as well as a number of international code specified spectra. Additionally, STAAD.Pro is interoperable with applications such as RAM Connection, AutoPIPE, SACS and many more engineering design and analysis applications to further improve collaboration between the different disciplines involved in a project. STAAD can be used for analysis and design of all types of structural projects from plants, buildings, and bridges to towers, tunnels, metro stations, water/wastewater treatment plants and more. The STAAD.Pro Graphical User Interface: it's wont to generate the model, which might then be analyzed mistreatment the STAAD engine. Once analysis and style are completed, the user interface also can be wont to read the results diagrammatically. The STAAD analysis and magnificence engine: it is a general calculation engine for structural analysis and integrated Steel, Concrete, Timber and metal vogue. To begin with we've got resolved some sample problems practice STAAD skilled and checked the accuracy of the results with manual calculations. The results were to satisfaction and were correct. With the initial section of our project we've got done calculations concerning loadings on buildings and conjointly thought of seismal and wind masses. Structural analysis contains the set of physical laws and arithmetic needed to review and predicts the behavior of structures.

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Structural analysis may be viewed additional abstractly as a way to drive the engineering style method or prove the soundness of a style while not a dependence on directly testing it. To perform associate in nursing correct analysis a structural engineer should confirm such data as structural masses, geometry, support conditions and material properties. The results of such Associate in nursing analysis generally embrace support reactions, stresses and displacements. This data is then compared to criteria that indicate the conditions of failure. Advanced structural analysis might examine dynamic response, stability and non-linear behavior. The aim of style is that the accomplishment of an appropriate likelihood that structures being designed can perform satisfactorily throughout their supposed life. With Associate in nursing applicable degree of safety, they ought to sustain all the masses and deformations of traditional construction and use and have adequate sturdiness and adequate resistance to the results of seismal and wind. Structure and structural elements shall normally be designed by Limit State Method. Account should be taken of accepted theories, experiment and experience and the need to design for durability. Design as well as style for sturdiness, construction and use in commission ought to be thought of as a full. The belief of style objectives needs compliance with clearly outlined standards for materials, productions, accomplishment and additionally maintenance and use of structure in commission. The planning of the building depends up on the minimum necessities as prescribed within the Indian customary codes. The minimum necessities relating the structural safety of building square measure being coated by manner of egg laying down minimum style (design) loads that got to be assumed for dead loads, obligatory loads and different external loads, the structural would be needed connected. Strict conformity to loading standards recommended in this code, it is hoped, will not only ensure the structural safety of the buildings which are being designed.

B. Advantages of STAAD PRO Software

i) Flexible modeling environment
ii) Availability of wide ranges for designing code
iii) Open architecture
iv) All feature of structural engineering
v) Report and documentation
vi) Quality assurances
vii) international code

Investigation of structure of different components of structure.

i) Planning of different parts of a structure with section situating
ii) Introduction of STAAD.Pro
iii) Modeling of the structure in the STAAD.Pro giving all limit conditions
(Underpins, stacking and so on)
iv) Analysis and Design of different basic parts of the modular structure
v) Study of investigation Data of the product
vi) Detailing of shafts, segments, piece with area proportioning and fortification.

C. Scope of the Study

1) Population Consideration: A population of 40,000 souls will be considered, which implies a significant water demand.
2) Tank Design Criteria: The water tank will be designed as a reinforced concrete structure. It will be an elevated type, with considerations for structural loads, seismic forces, and wind loads.
3) Use of STAAD Pro: STAAD Pro will be employed to carry out detailed structural analysis and to design the tank's main components (base, walls, and roof).
4) Loading Conditions: The tank will be designed for dead loads (structure weight), live loads (water pressure), wind loads, seismic loads (if applicable), and temperature variations.
5) Capacity Planning: The tank should be designed with a capacity that accommodates the daily water usage for the population, as well as emergency reserves.

6) IS Code Recommendations

The design and construction of water tanks in India follow guidelines set by the Bureau of Indian Standards (BIS). Some key IS codes include:

1) IS 3370: Code of practice for concrete structures for storage of liquids.

2) IS 456: General code of practice for plain and reinforced concrete.
3) IS 1893: Criteria for earthquake-resistant design of structures.

II. LITERATURE REVIEW

1) Design of Elevated Level Storage Reservoir (2019) By Tejaswi Koramutla & Anuskha.

Elevated Level Storage Reservoirs (ELSR) are essential for ensuring a continuous water supply, particularly in areas with growing water scarcity. These structures store water at a height to utilize gravity for distribution, eliminating the need for constant pumping. The design of ELSRs requires impervious concrete to prevent leakage and ensure durability, while accounting for loads such as dead load, live load, wind, and seismic forces. Tejaswi Koramutla and Anusha Sapatla's study focuses on designing an overhead tank for a population of 4,419 at the Annamacharya Institute of Technology and Sciences (AITS) using both manual calculations and software tools. The research highlights the importance of integrating technology in optimizing the structural dimensions and ensuring economical and efficient water storage solutions. With advancements in materials and design techniques, future reservoirs can incorporate sustainable practices to enhance environmental performance.

2) Behaviour of RC Overhead Water Tank Under Different Staging Patterns (2017) By Shrigondekar, Parulekar, and Kasar

Water tanks and especially the elevated water tanks are structures of high importance which are considered as main lifeline elements that should be capable of keeping the expected performance i.e. operation during and after earthquakes. Thus researchers, in recent years, have focused on studying seismic behaviors of these tanks, particularly ground tanks, while only few of these researches have concerned with the elevated tanks and even less with the reinforced concrete elevated tanks. Reinforced Concrete (RC) overhead water tanks are critical infrastructure components designed to ensure water availability and maintain operational performance during and after seismic events. Elevated tanks, in particular, are highly sensitive to seismic forces due to their height and structural configuration. The study by Shrigondekar, Parulekar, and Kasar focuses on the seismic behavior of an RC elevated water tank with a capacity of 400 m^3 under varying staging patterns. Using a linear dynamic analysis method, the researchers evaluated seismic responses such as base shear and tank displacement under empty tank conditions. Their findings highlight the significant impact of staging configurations on the tank's structural stability and performance. By comparing results across different configurations, the study provides insights into optimizing staging patterns to enhance seismic resilience, emphasizing the importance of tailored designs for elevated tanks in earthquake-prone areas.

3) Design and Analysis of Under Ground Water Tank Considering Different Fill Conditions Using STAAD.PRO (2022) By Deepshikha Gadekar, Rakesh Patel

Water tanks are essential structures for storing liquids, serving both domestic and commercial needs. The study by Deepshikha Gadekar and Rakesh Patel focuses on the design and analysis of a rectangular underground water tank with a capacity of 2 lakh liters, considering different fill conditions. Unlike overhead tanks, underground tanks must account for additional forces such as lateral earth pressure and water pressure, requiring precise calculations as per IS code standards. This project employs STAAD.Pro software for structural analysis, evaluating forces, moments, and deflections to ensure safety and efficiency. The design process covers key structural elements, including sidewalls, base slabs, and roof slabs, using the limit state method. The study highlights the importance of integrating advanced tools like STAAD.Pro for optimizing structural designs and ensuring the tank's stability and durability under varying load conditions.

4) Design Methods of Elevated Water Tank (2023) By Nikhil Yadav, Sunil Mane.

Elevated water tanks are vital components in water distribution systems, providing storage and maintaining pressure in the network. These structures, due to their slender staging and the large water mass at the top, are critical in ensuring water availability during natural disasters like earthquakes. The study by Nikhil Yadav and Sunil Mane emphasizes the significance of employing advanced design methodologies to enhance the safety and functionality of elevated water tanks. The research explores traditional and modern design approaches, focusing on the Working Stress Method and the Limit State Method as outlined in IS 3370. The Limit State Method, now included in the latest version of the code, is preferred for its superior strength and serviceability compared to the Working Stress Method. A key requirement in the design of water tanks is to ensure a crack-free structure to prevent leakage and corrosion, particularly under low-cycle fatigue caused by fluctuating water levels. This study underscores the importance of designing tanks with resilience to post-disaster conditions, prioritizing safety, durability, and sustainability.

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5) *Analysis and Economical Design of Water Tanks (2016) By Thalapathy M, Vijaisarathi R. P, Sudhakar P, Sridharan V, Satheesh V.S.*

Water tanks are essential structures used to store water and other liquids such as petroleum and similar substances, requiring designs that ensure crack-free structures to prevent leakage. The study by Thalapathy et al. explores the analysis and design of liquid-retaining structures using the Working Stress Method, focusing on three types of tanks: underground tanks, tanks resting on the ground, and overhead water tanks. The research emphasizes the importance of achieving a balance between safety and cost-effectiveness in tank design. Utilizing Microsoft Excel for analytical design, the study provides a framework for safe and economical water tank construction, including relationship curves between design variables to assist designers in optimizing structural parameters. This approach not only simplifies the design process but also ensures reliability and cost minimization, making it a valuable reference for understanding the fundamentals of water tank design.

6) *Design of Intze Water Tank by Using Staad Pro for Hathipur Village (2022) By Shivam Chaudhary, Anuj Verma, Nitish Katiyar, Parwez Ansari, Mr. Azeezurrahman Ansari*

Intze water tanks are a specific type of elevated water tank designed to supply water effectively in various applications such as domestic use, firefighting, irrigation, and agriculture. The study conducted by Shivam Chaudhary et al. focuses on designing an Intze tank for Hathipur village, Kanpur, using STAAD Pro software. The research outlines the importance of constructing water tanks that can withstand various natural loads such as earthquakes, wind, and extreme temperatures. Previous designs relied on older IS 3370-1965 codes, which resulted in thicker structural sections. With the advent of IS 3370-2009, more efficient and optimized designs are achievable. This study involves detailed analysis of load combinations, hydrostatic pressure, and stress conditions under full and empty tank scenarios. The research highlights the importance of ensuring crack-free construction to prevent leakage and maintain structural integrity. The project serves as a comprehensive guide for designing water tanks in rural areas, incorporating local data and modern design methodologies to ensure efficiency, durability, and cost-effectiveness.

7) *Economic Design of Water Tank of Different Shapes with Reference To IS: 3370 2009 (2014) By M. Bhandari, Karan Deep Singh.*

The study by M. Bhandari and Karan Deep Singh focuses on the cost-effective design of overhead water tanks with different shapes—circular, square, and rectangular—using the Limit State Method as per IS: 3370 (2009). It highlights the shift from the Working Stress Method (IS: 3370-1965), which resulted in thicker sections and higher reinforcement, to the more efficient Limit State Method. Circular tanks were found to be the most economical due to their smaller perimeter, which reduced material and formwork costs. Square tanks showed moderate cost-efficiency, while rectangular tanks were the least economical due to larger surface areas and higher material requirements. The study also emphasized the importance of checking crack width under serviceability conditions to ensure durability and leak resistance. Overall, circular tanks were concluded to be the most efficient and economical choice, especially for capacities of 100 kL, 150 kL, and 200 kL. This research provides valuable insights for selecting tank shapes based on cost and structural performance.

III. PROPOSED METHODOLOGY

1) Water Demand Calculation

The water demand per person is estimated using standard norms. Typically, a daily consumption of 150-200 liters per person is considered for urban areas, so the total water demand for 40,000 people would be calculated.

2) Tank Capacity Determination

The total daily water requirement for the population is multiplied by a storage factor (depending on the region's water supply and demand cycle) to determine the required storage capacity.

3) Structural Design using STAAD Pro

STAAD Pro will be used to analyze the following

- Structural Stability and Stress Analysis: Determine how the tank’s walls and base will handle the internal pressure and external loads.
- Design of Components: Design of the base slab, walls, and roof, considering reinforced concrete design codes.

- Seismic and Wind Load Analysis: Considerations for wind pressure and seismic loads will be performed to ensure the structure's stability in all conditions.

The software will output the stresses, moments, and shear forces for each structural element, and optimization will be performed to ensure that the design uses material efficiently.

4) Structural Design Considerations

- Material Selection: The tank will be constructed using reinforced concrete due to its durability and cost-effectiveness.
- Structural Elements:
  - Foundation/Base: A reinforced concrete slab will be designed to withstand the weight of the tank and the water.
  - Walls: The walls of the tank will be designed for both hydrostatic pressure from the water inside and external loading.
  - Roof: An appropriate roof design will be created to cover the tank while allowing for maintenance and preventing contamination.
- Safety Factors: STAAD Pro will help ensure that all safety factors, including overload conditions, dynamic loads, and fatigue, are well within allowable limits.

5) Design Loads

- Dead Load: Weight of the water tank structure.
- Live Load: Water load (weight of the water stored inside the tank).
- Wind Load: Based on the region's wind zone.
- Seismic Load: If the region is seismic, seismic forces will be applied according to the local seismic codes.
- Temperature Effects: Thermal expansion and contraction will be considered in the design of the structure.

IV. CONCLUSION

The selection and design of a water tank for a town with a population of 40,000 require a thorough understanding of demand estimation, structural stability, and material properties. RCC tanks are generally preferred due to their durability and cost-effectiveness, while steel tanks offer quick installation and flexibility. By adhering to IS codes and incorporating sustainability principles, an efficient and long-lasting water storage system can be designed.

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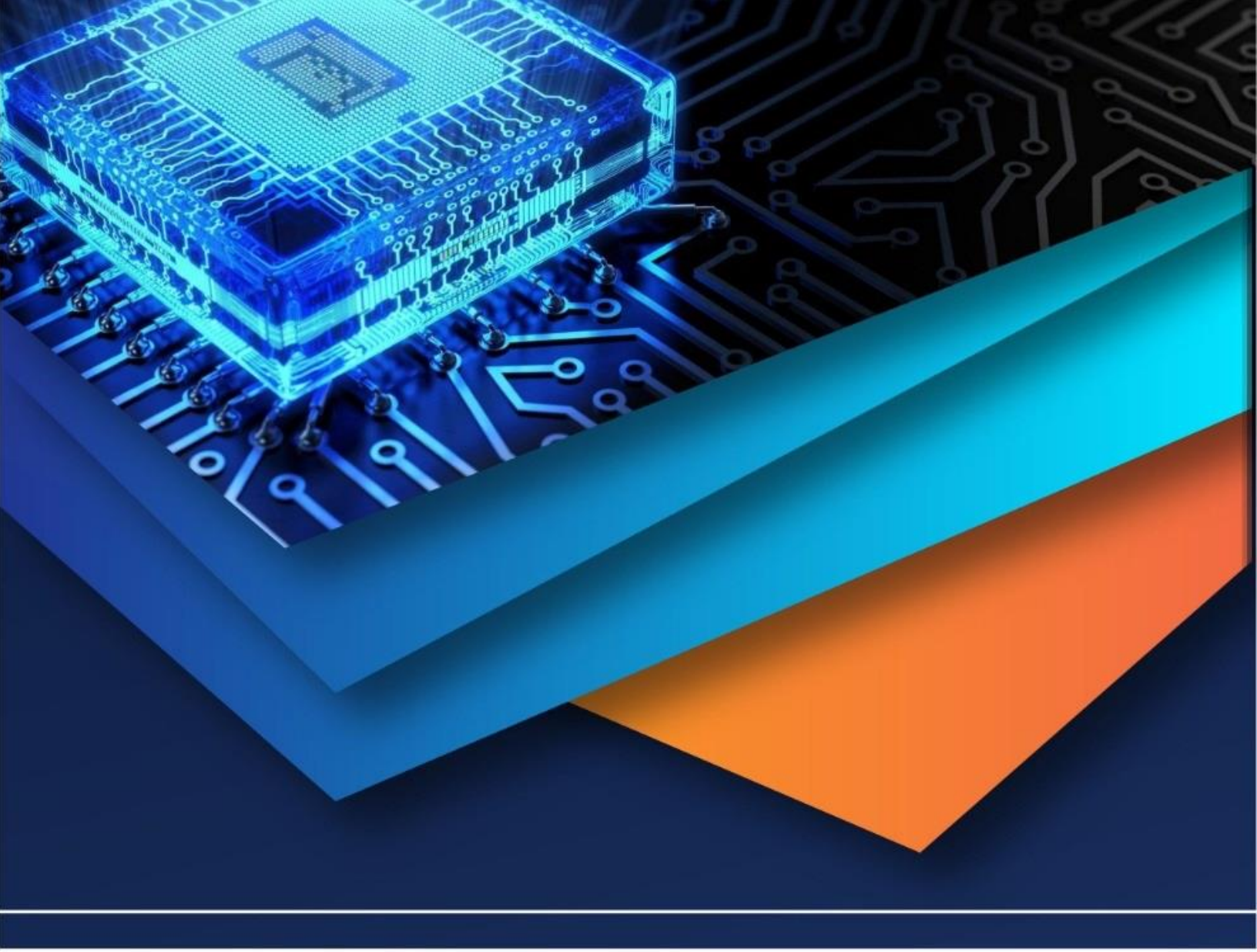

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