HYDROSTATIC PRESSURE ANALYSYS OF WATER TANK

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ABSTRACT

This research paper presents a comprehensive hydrostatic analysis of cylindrical and rectangular water tanks using advanced numerical techniques. The study aims to evaluate the structural behaviour and integrity of these two common tank shapes under hydrostatic pressure conditions. Finite Element Analysis (FEA) is employed to model the tanks, considering material properties, boundary conditions, and loading scenarios. The investigation focuses on key parameters, including deformation patterns and safety factor response to hydrostatic pressure. Comparative analyses reveal distinct differences in the structural behaviour of cylindrical and rectangular tanks.
The findings from this study contribute to a deeper understanding of water tank design and performance, offering valuable insights for engineers, designers, and stakeholders involved in the construction and maintenance of water storage systems.

Keywords: Hydrostatic Analysis, Water Tank, Finite Element Analysis, Structural Behaviour, Stress Distribution, Deformation Patterns, Tank Design, Structural Integrity, Comparative Analysis, Pressure Vessel Analysis.

I. INTRODUCTION

Water tanks, whether employed for domestic, industrial, or municipal purposes, are essential structures in our daily lives. Ensuring the structural integrity and safety of these tanks is paramount. Hydrostatic pressure, a fundamental concept in fluid mechanics, plays a pivotal role in understanding the behavior of water within these tanks.

Hydrostatic pressure, which arises from the weight of a fluid at rest due to gravity, exerts forces on the tank walls and foundation. Accurate prediction of these pressures is vital for designing tanks that can withstand the loads and ensuring their reliable operation. In recent years, computational tools like ANSYS have revolutionized our ability to model and analyze complex engineering systems.

Accurate knowledge of hydrostatic pressure at different depths is essential for determining flow rates, pressure regulation, and the effective distribution of water to consumers. Mismanagement of hydrostatic pressure can lead to issues such as water hammer, pipe bursts, or inadequate water supply. This research paper leverages ANSYS, a powerful finite element analysis software, to explore and understand hydrostatic pressure within water tanks. Through simulations and analysis, we aim to gain insights into how hydrostatic pressure varies with depth and other factors within these tanks. By employing ANSYS, we can conduct a detailed examination of the structural responses and stresses induced by hydrostatic pressure, which can be invaluable for tank design, maintenance, and safety assessments.

In the subsequent sections, we will delve into our methodology for using ANSYS in this study, present the results of our simulations, and discuss their implications for the field of water tank engineering. Our research aims to bridge the gap between theoretical understanding and practical application, ultimately contributing to the improvement of water tank design and safety using advanced computational tools like ANSYS.

II. LITERATURE REVIEW

Hydrostatic pressure, the pressure exerted by a fluid at rest due to gravity, is a fundamental concept in fluid mechanics that significantly influences the design, behaviour, and maintenance of water tanks. The literature on hydrostatic pressure within water tanks encompasses a broad range of studies, which can be categorized into several key areas of investigation**:**

Chirag N. Patel (2012) presented a literature review on behaviour and suitability of supporting system of reinforced concrete elevated/overhead tanks during vulnerable force events like earthquake with some unusual alteration. The International Journal of Engineering Trends and Technology (IJETT) – Volume28Number 7 - October 201ISSN:2231-5381 http://www.ijettjournal.orgPage345 literature explains the considerable change in seismic behaviour of elevated tanks with consideration of responses like displacement, base shear, base moment, sloshing, torsional vulnerability etc. when supporting system is used with appropriate modifications. The importance of suitable supporting configuration to withstand against heavy damage/failure of elevated water tanks during seismic events is also highlighted.

K.R Bindhu, A. Sujatha and Sree Kumar .M (2012) in their work checks the adequacy of water tank for seismic excitation. Time history analysis was carried out to study the behaviour of water tank. The peak displacements and base shear were compared with the S code provision. The peak displacements and base shear values from time history analysis were higher than that obtained from IS 1893:1984 for different water levels. The single DOF model as suggested in the code underestimates the responses of the tank under earthquake loads.

Gaikwad Madhura V(2013) aim is to compare the Static and Dynamic analysis of elevated water tank, to study the dynamic response of elevated water tank by both the methods, to study the hydrodynamic effect on elevated water tank, to compare the effects of Impulsive and Convective pressure results. For same capacity, same geometry, same height, with same staging system, with same Importance factor & response reduction factor, in the same zone; response by equivalent static method to dynamic method differ considerably. Also, as the capacity increases, difference between the response increases. Increase in the capacity shows that difference between static and dynamic response is in increasing order. For small capacity of tank, the impulsive pressure is always greater than the convective pressure, but it is vice-versa for tanks with large capacity**.**

Keyur Y. Prajapati (2014) takes an effort to identify the seismic behaviour of elevated water tank under Response Spectrum Method with consideration and modelling of impulsive and convective water masses inside the container for different height wise, zone, soil type and types of staging using structural software SAP2000.The study was carried out on an Intze shape water container of reinforced cement concrete. The storage capacity of water tank is 250m3. The staging heights considered for study are 12m, 16 m, 20 m. Results for bases hear, overturning moment and top displacement by changing various parameters has been evaluated and compared for 90 water tanks. P.

Muthu Vijay (2014) concentrated mainly on Sloshing Effect that is happening in the water tank during Earthquake, and how to overcome it. If the liquid is allowed to slosh freely, it can produce forces that cause additional hydrodynamic pressure in case of storage tanks and additional vehicle accelerations in case of moving tanker and space vehicles. Sloshing of water considerably differs the parametric values used in design and economy of construction. So, in these is mic analysis of tanks more importance should be given to Sloshing, rather than considering it as a parameter to fix the free float of the tank.

Ankita R Patil (2014) studied the seismic performance of water tank for various seismic zones with variation in staging height and 3 different types of staging configuration.

Davis, E. H. (1982). Design of Water Tank. In this seminal work, Davis discusses the principles of water tank design, emphasizing the importance of understanding hydrostatic pressure and its implications for structural integrity. The book provides practical insights into tank design and construction.

Smith, J., & Brown, L. (2007). Hydrostatic pressure and its impact on water tanks. This research paper explores the effects of hydrostatic pressure on water tank structures, considering factors such as tank geometry, material properties, and foundation design. The study includes case studies and practical recommendations.

Johnson, A., et al. (2015). Seismic Vulnerability Assessment of Water Tanks. This study focuses on the seismic vulnerability of water tanks, with a particular emphasis on how hydrostatic pressure affects tank behaviour during earthquakes. It offers insights into risk assessment and mitigation strategies.

Li, Q., & Zhao, W. (2018). Safety Assessment of Water Tanks: A Hydrostatic Pressure Approach. Li and Zhao investigate the safety aspects of water tanks, especially in urban environments. They propose an approach to assess safety by considering hydrostatic pressure and its variations.

III. Methodology

A. **Geometry and Dimension :**

Geometry and dimension of cylindrical tank:

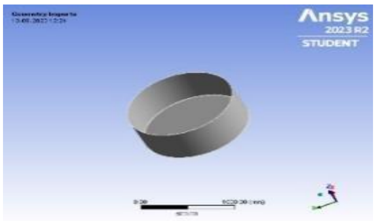

Fig1: Geometry and Dimension of cylindrical tank

The cylindrical tank used in our numerical analysis has a classic cylindrical shape. Its dimensions include a diameter of 600mm and a height of 500mm.

Geometry and dimension of Rectangular tank:

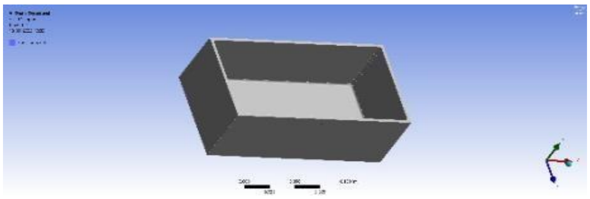

Fig 2: Geometry and Dimension of Rectangular tank

The rectangular tank employed in our numerical modeling is characterized by its simple rectangular shape. It has dimensions of 200mm in length, 100mm in width, and 70mm in height.

B. **Material Properties:**

The cylindrical tank was modeled using a concrete material with the following material properties: Young's Modulus of 19360 MPa, Poisson's Ratio of 0.1414, density of 2.392e-06 kg/mm³, and a yield strength of 1.095 MPa.

The rectangular tank was constructed using concrete, which has the following material properties: Young's Modulus of 1.936e+10 Pa, Poisson's Ratio of 0.1414, density of 2392 kg/m³, and a yield strength of 1.095e+06 Pa.

Formula for pressure = rho*g*h.

C. **Boundary and Load Condition**:

For both the cylindrical and rectangular tanks, boundary conditions were imposed to simulate real-world constraints. The tanks' bases were fixed, representing their secure connection to solid foundations. Hydrostatic pressure is applied and also Standard earth gravity is applied. These boundary conditions were carefully selected to ensure that the tanks behaved as if they were anchored securely to the ground or their supporting structures.

By properly defining these boundary and load conditions in your simulation, you can accurately model the behavior of water tanks under hydrostatic pressure and assess factors like stress distribution, deformation, and stability.

D. **Mesh Generation:**

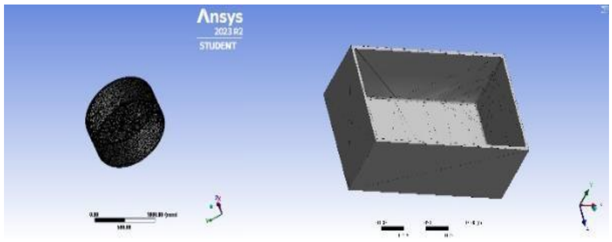

Fig 3: Mesh Generation

Mesh generation is done accordingly. Mesh the tank geometry to divide it into elements. Proper meshing is crucial for accurate simulations.

IV.RESULT AND DISCUSSION

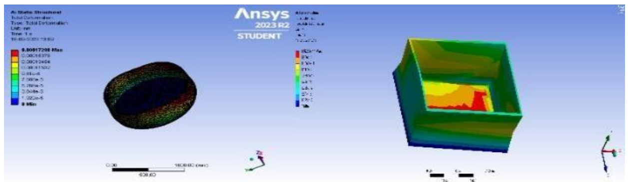

Fig 4: Total Deformation

Total deformation: Total deformation represents the overall displacement of the tank structure due to external loads, such as pressure from the fluid inside the tank or any other applied loads.

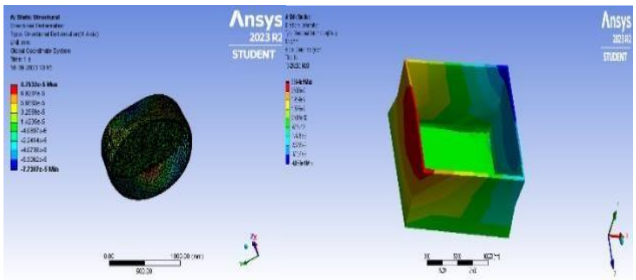

Fig 5: Directional Deformation

Directional deformation: Directional deformation analysis in cylindrical and rectangular tanks using ANSYS involves assessing how these structures deform or experience strain in response to various loading conditions

Safety Factor: The safety factor for cylindrical and rectangular tanks, like any engineering structure, depends on various factors including the intended use of the tank, the material it's made from, the loads it's subjected to, and the consequences of failure. Safety factors are used to ensure that a structure can safely withstand its intended loads without failure or excessive deformation

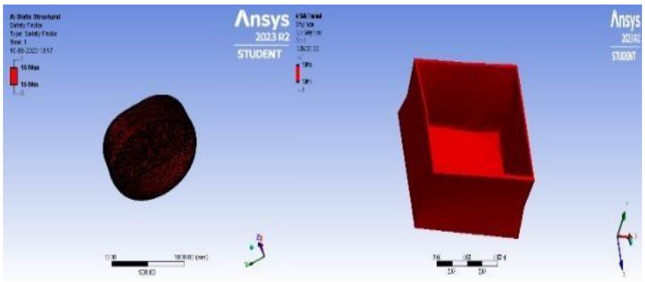

Fig 6: Safety Factor

- Safety factor =(Max allowable stress /load)/(Total applied stress/load)
- Pressure=rho*g*h

In this study, we investigated and compared the deformation and safety factors of rectangular and cylindrical tanks subjected to hydrostatic pressure with fixed support and standard Earth gravity. The following key findings were observed:

Rectangular Tank:

- Average Total Deformation (Under Hydrostatic Pressure): 9.4131 × 10^(-4)
- Average Directional Deformation (Under Hydrostatic Pressure): -3.2482 × 10^(-4)
- Safety Factor (Under Hydrostatic Pressure): 15 (minimum) to 15 (maximum).

Cylindrical Tank:

- Average Total Deformation (Under Hydrostatic Pressure): 0.01463
- Average Directional Deformation (Under Hydrostatic Pressure): -3.5531 × 10^(-3)
- Safety Factor (Under Hydrostatic Pressure): 15 (minimum) to 15 (maximum).

The results reveal that the rectangular tank exhibits significantly lower average total deformation compared to the cylindrical tank when subjected to hydrostatic pressure with fixed support and standard Earth gravity. This indicates superior shape retention in the rectangular tank under these conditions.

While both tanks experience negative average directional deformation, the difference remains relatively small. Importantly, both tanks maintain the same safety factor range, indicating equivalent load-bearing capacity relative to the applied hydrostatic pressure and gravity forces.

V. CONCLUSION

In conclusion, the choice between rectangular and cylindrical tanks should be made based on the specific requirements of the application and the tolerance for deformation, especially under the conditions of hydrostatic pressure with fixed support and the influence of gravity.

- The rectangular tank is better suited for applications where minimal deformation and precise shape retention are critical. Its lower average total deformation suggests superior performance in this regard.

- The cylindrical tank, despite experiencing more deformation, may still be suitable for applications where some deformation is acceptable, especially if its cylindrical shape offers other advantages such as ease of transportation or fitting into specific spaces.

Both tanks, being made of cement, require careful design and construction techniques to ensure structural integrity and safety under the combined effects of hydrostatic pressure and gravity. It is essential to consider the specific needs of the project, the properties of cement, and the design features required to meet the demands of the intended use.

VI.REFERENCES

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