Time History Analysis of Underground Water Tank Considering Earth Pressure

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Abstract- *Different types of reservoirs and water tanks are used to store a variety of liquids, including chemicals, water, and petroleum. Water tanks are necessary for both residential and commercial use in order to satisfy the everyday needs of the people who reside in these locations. Both the internal water pressure and the external earth pressure are applied to these tanks over the course of their existence. Soil reaction from the bottom and internal water pressure from the inside are applied to the tank bases. Consequently, they are always covered from top to bottom to ensure complete protection. This rectangular subterranean tank is designed to provide the ideal height for convenient water pumping to the overhead tank.Design calculations must take into account both water pressure and lateral earth pressure because the water tank is underground; therefore, the design must adhere to IS code criteria. This concept designs a rectangular tank that is subterranean.*

This design project employs the limit state method. Shear force and bending moment are two examples of water tank parameters that researchers study to better understand how they react to seismic forces and to help with more efficient design and construction.

Keywords- Earth pressure, STAAD.Pro, Tank bases, Seismic Analysis, Underground tanks.

I. INTRODUCTION

Environmental engineering structures that contain concrete liquid are regarded as vital infrastructure during seismic activity. The contents of water tanks are crucial for firefighting operations and for satisfying public requests, even though leaks from tanks holding dangerous materials must be regulated. The dynamic reaction of liquid storage tanks has been the subject of extensive investigation up to this point. Most of them, nevertheless, have something to do with steel tanks. Reinforced concrete tanks have not received much attention. Rectangular or circular reinforced concrete tanks are frequently utilised in environmental engineering applications. To satisfy safety objectives while keeping construction and maintenance costs under control, it is essential to have a solid understanding of how these structures behave seismically.

Structures known as underground water tanks serve as reservoirs for modest residential or commercial buildings. Subterranean water tanks are primarily composed of the base slab, side walls, and roof slab. Because tanks are so ductile, they can tolerate different water backfill and earthquake stresses. Tanks make optimal use of materials, using concrete in compression and steel in tension. Subterranean water tanks require little upkeep over their lifetime because they are constructed of concrete, a strong material that never corrodes and doesn't need to be coated when exposed to water or the elements. The primary benefit of an underground water tank is that it will have less evaporation because the temperature is lower than that of a roof-top tank.Earth pressure, water pressure, or any liquid pressure contained in the tank are the main causes of the horizontal or lateral stresses that underground water tanks experience in contrast to other types of constructions. More weight will be placed on the underground water tank's side walls at the bottom, and the load will progressively lessen as it rises.

In addition to internal loads, the subterranean water tank must also support the surcharge above ground level. Therefore, the subterranean tank's roof slab should be strong enough to withstand the surcharge.

II. OBJECTIVES OF THE RESEARCH

- Analysis UG water tank using Time Historyanalysis method
- Study the guidelines for the design of liquid retaining structure according to the IS Code.
- To know about the design philosophy for the safe& economical design of UG water tank.
- The deflected shape of the tank is being analyzed
- To reduce the tedious calculation
- To compare the IS code design method with various software design results.
- To understand governing loads and carry out a literature review related to the underground water tank.

- To study the base deflection criteria, shell stresses and joint reaction of underground water tank structure by considering earth pressure loading when the tank is empty and full water level conditions.

III. LITERATURE REVIEW

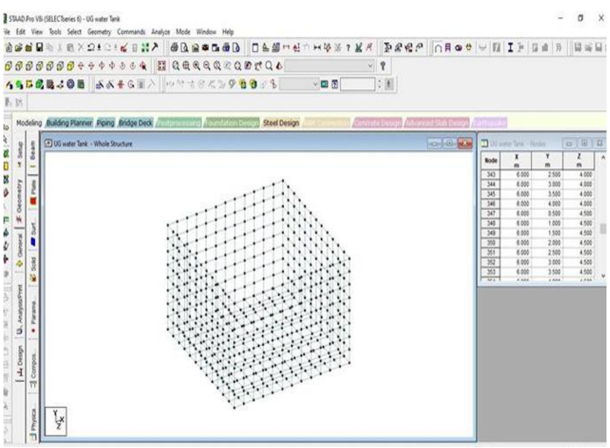
Nitin Chaturvedi and Santosh Kumar Kharole (2025) focused on examination of rectangular overhead water tank of a reinforced concrete building using STAAD Pro V8i SS6 software considering seismic zone II.

Results stated that ground pressure has a major impact on the overall force operating on the tank structure, indicating that it should be considered during design and analysis to ensure structural stability and safety. This implies that earth pressure reduces the tank structure's shear stress, which may affect structural and design problems. These forces need to be accurately evaluated in order for the design process to be secure and stable. This will enable them to create better designs that effectively offset the various forces acting on the building, enhancing its robustness and security.

IV. METHODOLOGY

STEPS INVOLVED IN MODELLING AND ANALYSIS OF UNDEGROUND STORAGE WATER TANK

Step 1: To prepare geometry of the UG structure using analysis tool Staad.pro



Step 2: To create material for structural sections.

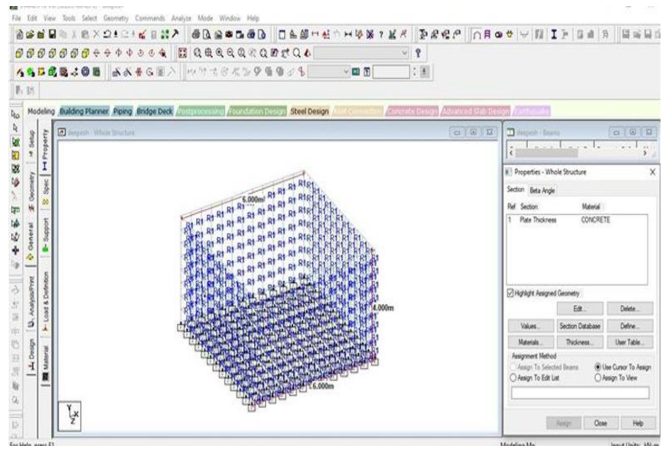


Fig Geometric View of UG water tank

Step 3: To Assign and create sectional properties

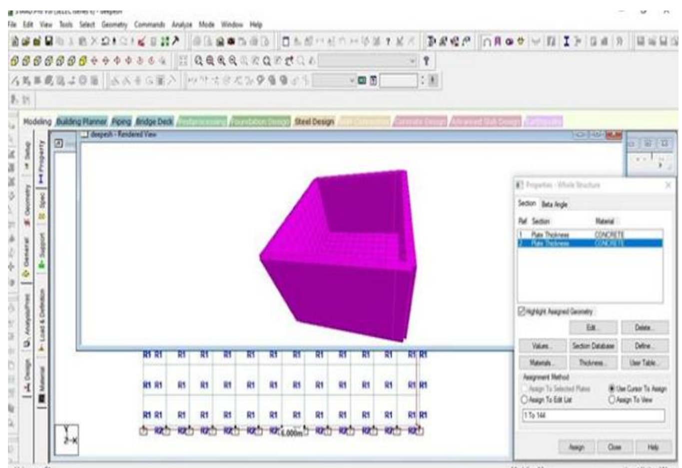


Fig Defining Section Properties

Step 4: Assign supports at base

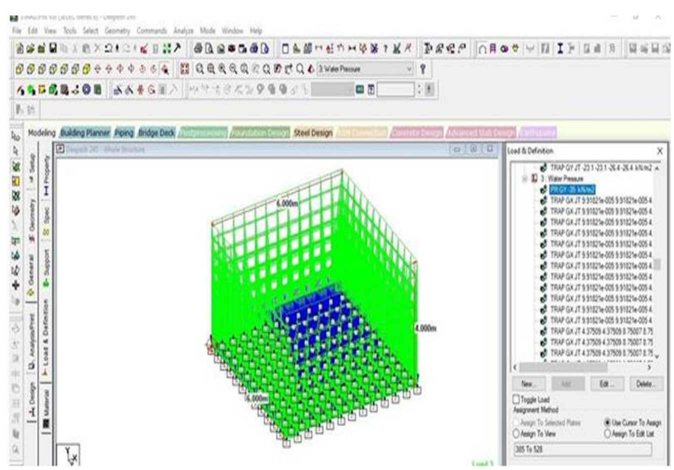
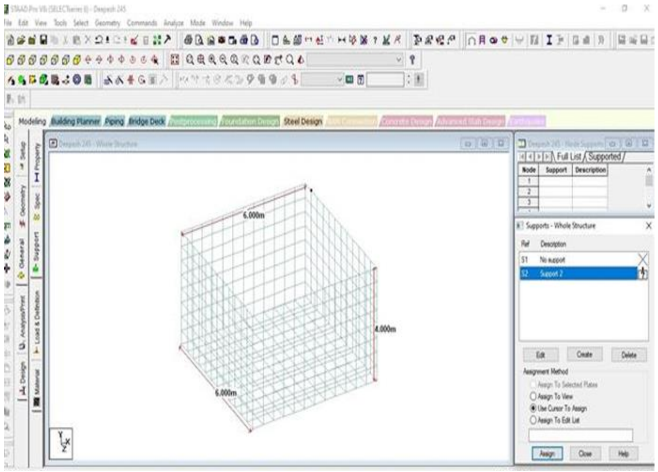


Fig Assigning Support Condition

Step 5: Assigning Hydrostatic Pressure



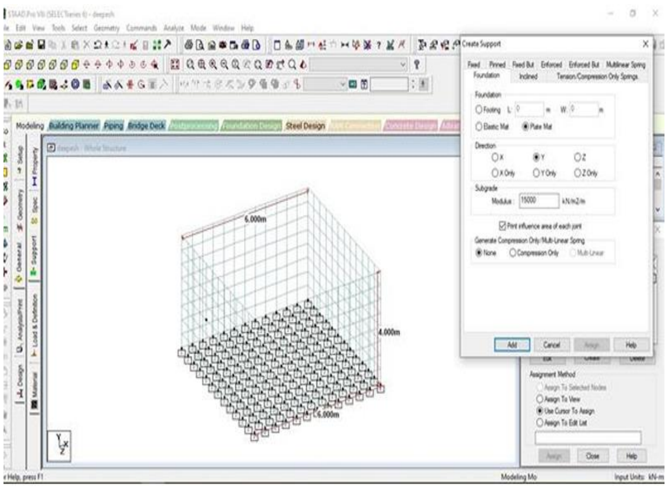


Fig Hydrostatic Pressure

Step 6: Assigning Backfill Condition.

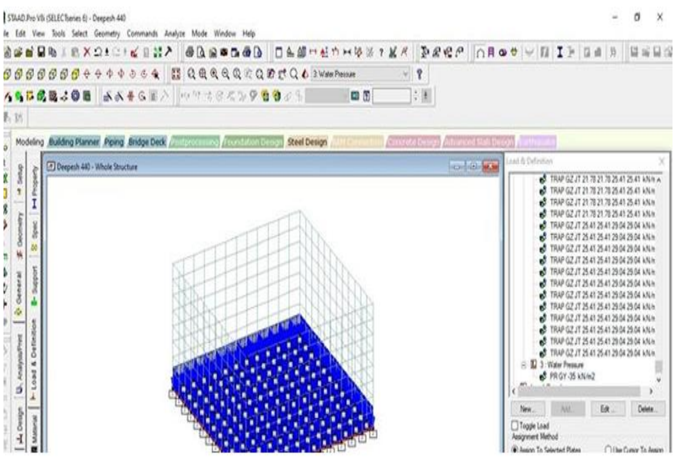


Fig Backfill for moist clay condition

Step 7: Analysis of structure using analysis tool Staad.pro

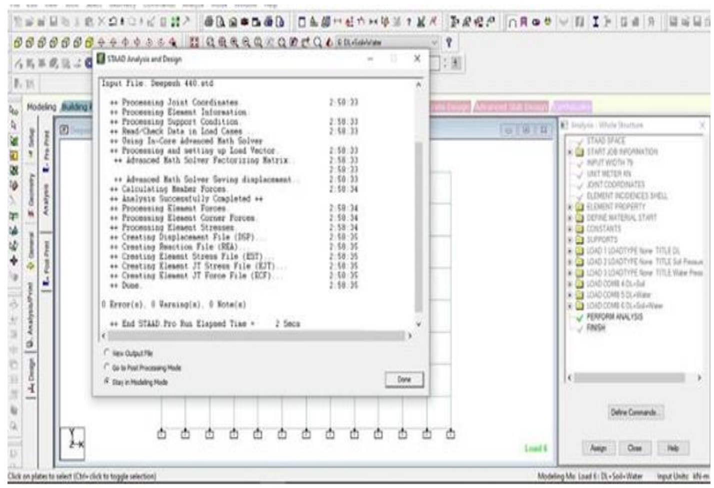


Fig Perform Analysis

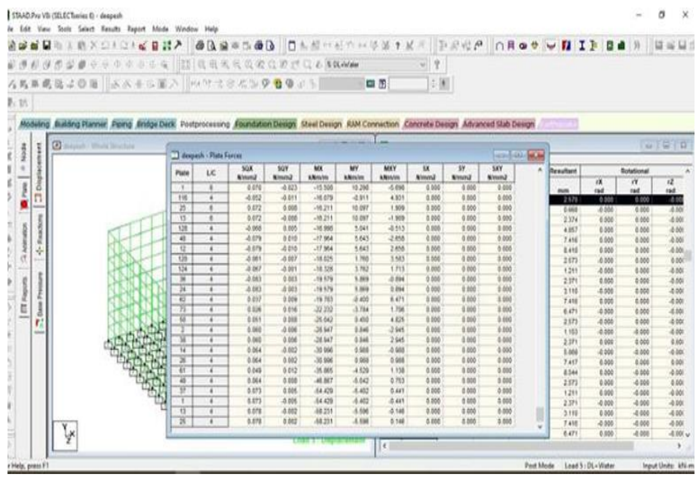


Fig Plate Stress Analysis

V. RESULTS AND DISCUSSION

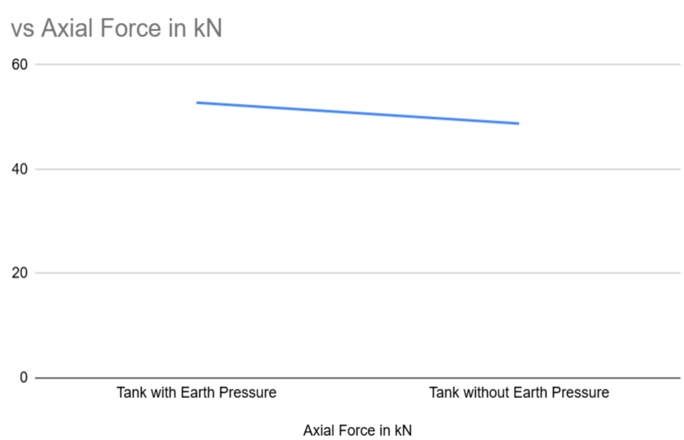


Fig Axial Force in kN

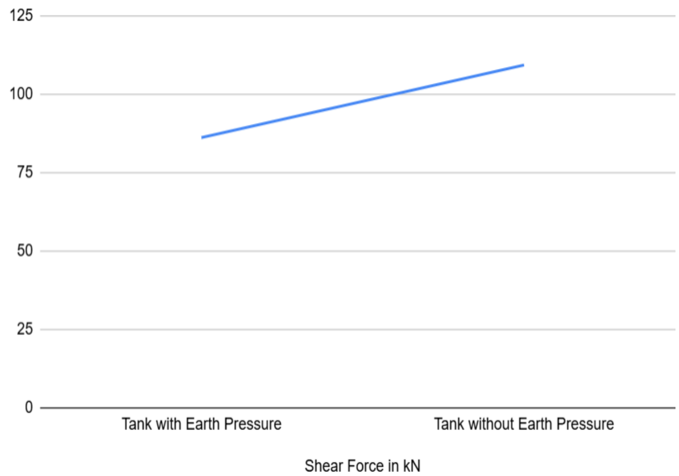


Fig Shear Force in kN

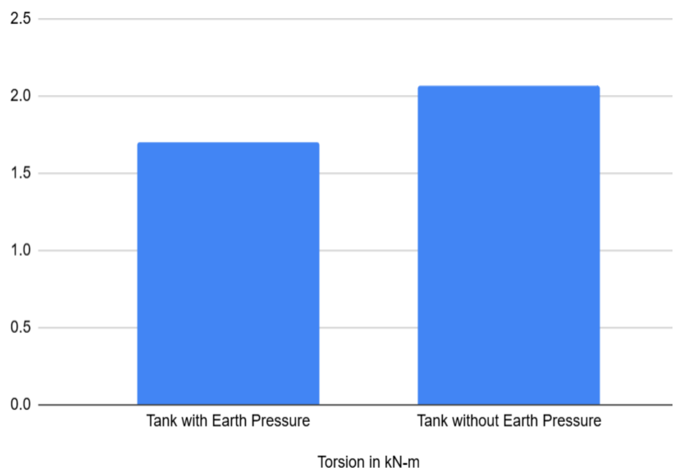


Fig Torsion Moment in kN-m

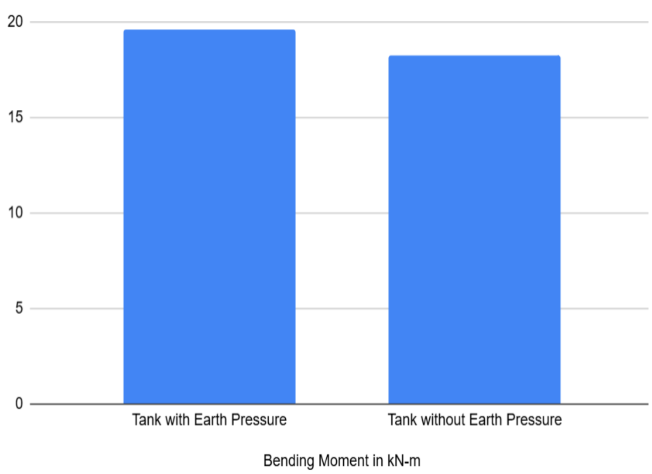


Fig Bending Moment in kN-m

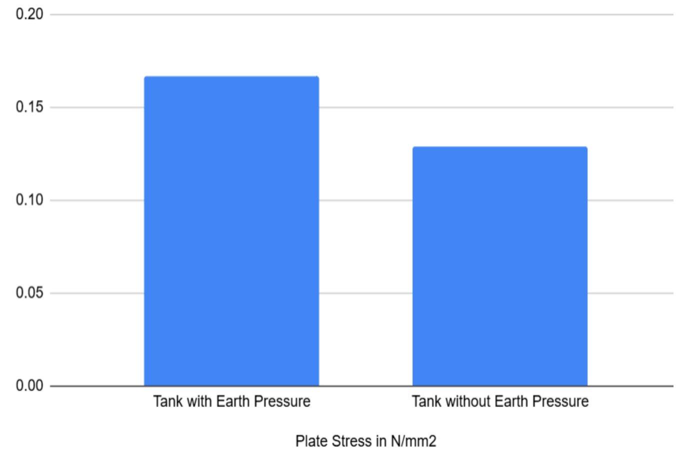


Fig Plate Stress in N/mm2

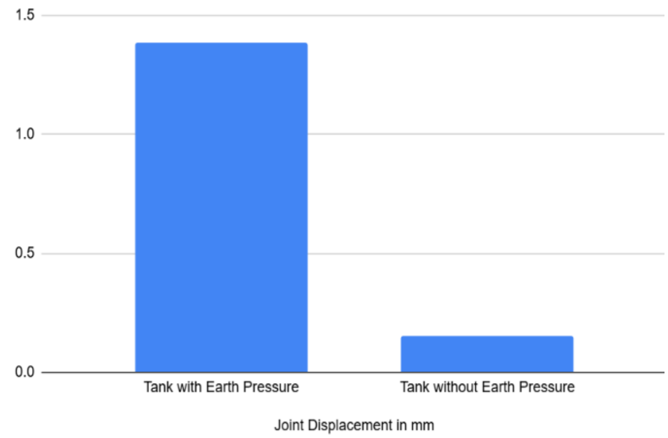


Fig Joint Displacement in mm

VI. CONCLUSION

Axial Load

The axial force in the tank subjected to earth pressure is notably higher, recorded at 52.752 kN, compared to 48.749 kN for the tank without earth pressure—an increase of approximately 4.003 kN or 8.21%. This highlights the considerable influence of lateral soil loads on structural behavior in subterranean or semi-buried conditions. Scientifically, the presence of earth pressure introduces additional vertical and horizontal stresses, emphasizing the necessity of incorporating such forces accurately in structural analysis and design to ensure the tank's safety, serviceability, and long-term durability.

Shear Force

The measured shear force values reveal a counterintuitive trend, with higher shear observed in the absence of earth pressure (109.344 kN) compared to 86.209 kN when earth pressure is applied—reflecting a 21.19% reduction. This difference is scientifically attributed to the lateral confinement provided by surrounding soil, which enhances load distribution and structural stability, thereby reducing localized shear effects. In contrast, the absence of earth pressure leads to unbalanced internal forces, increasing shear demands. These findings underscore the critical role of boundary conditions and soil-structure interaction in accurately evaluating the structural performance of underground tanks.

Torsion Moment

When earth pressure is applied, the torsional moment is reduced to 1.701 kN·m, compared to 2.064 kN·m without earth pressure—an increase of approximately 21.4%. This rise in torsion in the absence of earth pressure is scientifically attributed to the lack of lateral confinement, which allows greater unrestrained deformation. Surrounding soil provides passive resistance that mitigates torsional effects by stabilizing the structure against uneven loading or asymmetric stress conditions. Without this confinement, the structure becomes more susceptible to twisting due to external forces such as seismic activity or differential settlement.

Bending Moment

The bending moment is observed to be higher when earth pressure is considered, measured at 19.628 kN·m, compared to 18.228 kN·m without it—an approximate increase of 7.7%. This rise is scientifically attributed to the lateral confinement exerted by surrounding soil, which introduces additional distributed loads on the tank walls, thereby increasing flexural demands, particularly in vertical sections. In contrast, tanks without earth pressure primarily respond to self-weight and internal fluid forces, resulting in lower bending responses. These findings underscore the critical importance of soil-structure interaction (SSI) in the structural analysis of underground tanks and highlight the need for reinforced design strategies to accommodate elevated bending stresses in geotechnically active environments.

Plate Stress

The data reveals that plate stress rises to 0.167 N/mm² when earth pressure is included, compared to 0.129 N/mm² without it—representing an approximate 29.5% increase. This significant elevation in stress is attributed to the additional lateral and vertical loads imposed by surrounding soil, which introduces new stress paths that influence the structural response of the tank's plate elements. These elements, due to their thin-walled nature, are particularly sensitive to combined membrane and bending stresses induced by the distributed earth loads. Conversely, in the absence of earth pressure, the tank experiences only internal hydrostatic pressure and self-weight, resulting in comparatively lower stress levels. This analysis underscores the necessity of accounting for soil-induced confinement in the design of buried tank structures to ensure structural adequacy and long-term durability.

Joint Displacement

The data demonstrates a substantial increase in joint displacement due to earth pressure, rising from 0.155 mm (without earth pressure) to 1.385 mm when such pressure is present—an approximate increase of 793.5%. This pronounced change highlights the critical impact of lateral soil confinement on deformation behavior. Structurally, the presence of earth pressure introduces additional external forces beyond internal fluid stresses, amplifying bending and shear effects at the joints. These augmented forces result in greater displacement, which may compromise serviceability, particularly by affecting joint integrity, water-tightness, and the overall durability of the tank structure in geotechnically active environments.

6.2 Future scope

- Furthermore, the analysis can be carried out by considering Circular shape as well as other shapes of underground water tanks.
- The above analysis should be verified for soil structure Interaction effect.
- The present work is extended to carry out seismic analysis as per BIS code.

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