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Seismic Analysis of Cylindrical Precast OHT for Critical Zones

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ABSTRACT

Water is life line for every kind of creature in this world. All around the world liquid storage tanks are used extensively by municipalities and in-dustries for water supply, firefighting systems. Water tanks play an im- portant role for public utility as well as industrial structure with basic purpose to supply water with constant head to long distance to the desired location under the effect of gravitational force. Tanks are designed as crack free structures to eliminate water leakage. The research involves a comprehensive investigation of the structural behavior of the circular precast OHT equipped with a pier cap under seismic loads. The study encompasses analytical approaches. The analytical aspect involves a de-tailed literature review on seismic design principles, precast construction techniques, and pier cap design considerations. Subsequently, a comprehensive structural analysis is conducted, considering various seismic in-tensity levels, ground motion characteristics. The study's outcomes en- hance understanding of dynamic behavior, failure modes, and stress dis- tributions during seismic events. This research contributes to optimizing the design of circular precast OHTs with pier caps, thus bolstering their resilience in critical seismic zones and guiding further advancements in safeguarding crucial infrastructure. In subsequent stages, the project em-barks on a detailed comparative study between the two tank designs within the context of varying seismic zones. Dynamic characteristics for response spectra, are meticulously evaluated for both cylindrical precast OHTs and Intze tanks. These analyses are performed to assess the relative performance and vulnerabilities of cylindrical precast overhead tank compared to the traditional Intze tank design.

Keywords: Base shear, Storey Stiffness, Precast overhead Tank, Intze Tank, Displacement and StaadPro.

Water is a very precious natural resource. The term "reservoir" is com- monly used to describe structures for storing liquids, which can be situ- ated either below or above ground level. Below-ground reservoirs are typically constructed for the storage of large water quantities, while above-ground reservoirs, designed for gravity-based distribution, tend to have smaller capacities. It is crucial that elevated tanks continue to func- tion after an earthquake to ensure a reliable water supply in affected ar- eas. Unfortunately, numerous elevated tanks have suffered damage or collapse during previous seismic events. As a result, it is imperative to comprehend the seismic behavior of elevated tanks and implement earth- quake-resistant designs for them.

In our country, the water supply system relies on elevated tanks for stor- age. These tank structures are susceptible to lateral forces such as earth- quakes due to the significant mass concentrated at the top of their slender supporting framework. Consequently, it is crucial to emphasize the seis- mic design of reinforced concrete liquid storage tanks due to the poten- tially dangerous consequences associated with their failure during earth- quakes. Historical incidents have highlighted extensive damage and col- lapse of elevated water tanks during seismic events, which may be at- tributed to insufficient understanding of the structural behavior under dy- namic forces and improper selection of geometric configurations for staging. Furthermore, instances of tank and reservoir failures have oc- curred not solely due to specification shortcomings but also due to other reasons that because of the failures of water tanks.

Objectives

- To assess the performance of Precast overhead tank with intze tank under seismic loading conditions.
- To conduct Response Spectrum Analysis in order to study the dy- namic characteristics of the structure in the given seismic area.
- To propose precast OHT in required zone based on the optimum results obtained from the analysis results.

Methodology

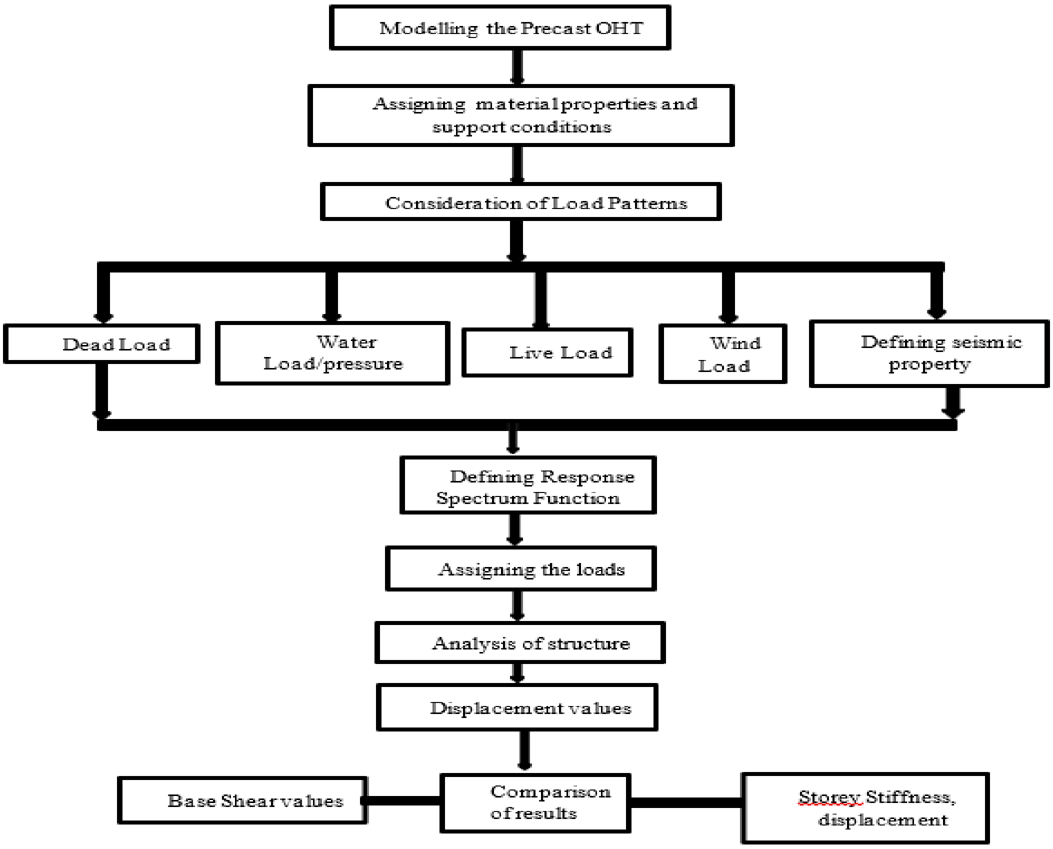

Fig.1 Flowchart of methodology

DETAILS OF BUILDING

Table 1. Model Data – Precast OHT

Component	Diameter (m)	Thickness (m)	Height (m)
Top Dome	5	0.13	-
Cylindrical Wall	5	0.2	4
Mono-column	1.40	-	13.8
Pier Cap	1.95	0.3	0.6

Table 2. Model Data – Intze Tank

Component	Diameter(m)	Thickness (m)	Height (m)
Top Dome	5	0.13	
Cylindrical Wall	5	0.2	4
Conical Dome	5, 3.5	0.2	0.75
Bottom Dome	3.5	0.2	
Staging			14.5
Bracings			
Component	Breadth (m)	Depth (m)	Diameter (m)
Tie Beam	0.3	0.4	
Ring Beam	0.3	0.3	
Circular Column			0.4

Precast Overhead Tank

Precast overhead tanks represent a modern and efficient approach to water storage solutions, utilizing precast concrete components for rapid and streamlined construction. The distinctive feature of precast overhead tanks lies in their construction method, which involves manufacturing standardized concrete sections off-site. These sections are then trans- ported to the installation site and assembled to create the tank structure. This approach significantly reduces construction time and minimizes disruption to the surrounding environment. Precast overhead tanks offer advantages such as enhanced quality control, reduced on-site labor re- quirements, and improved structural integrity. These tanks can be de- signed to various capacities, accommodating the specific water demand of the area they serve. Additionally, their modular nature allows for fu- ture expansion or relocation if needed.

Modelling and Analysis

In the present study, Precast overhead tank with pier cap is considered and an Intze tank having the same aspect ratio is considered for the study.

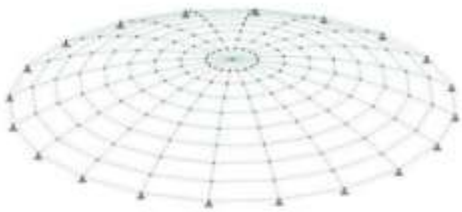

Fig.2 Top Dome

Fig.3 Pier Cap

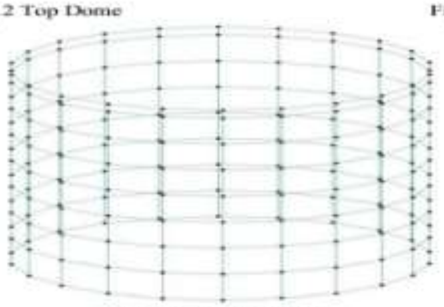

Fig.4 Cylindrical Wall

Fig.5 Node view of Precast OHT model

Fig.6 3D Rendering view of Precast OHT model

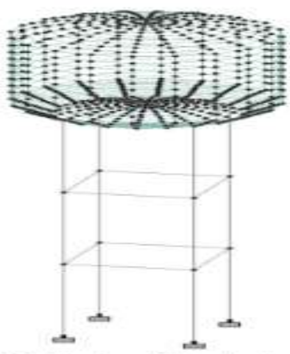

Fig.7 Node view of Intze Tank model

Fig.8 3D rendering view of Intze Tank model

RESULTS AND DISCUSSIONS

In the results part, for each seismic zone (II, III, and IV), four sets of models exist, that is: -

- Model 1 - Precast OHT
- Model 2 - Intze tank

The following graphs represent the variation in the values of Base shear, storey drift, storey stiffness, storey displacement for the following tanks in different seismic zones.

Base Shear

The base shear represents the total lateral force that the structure's foundation must resist during an earthquake. From IS1893:2016, the base shear is the product of the design spectrum acceleration and the seismic weight of the building. $V_b = A_h \times W$ where the A_h is the spectrum acceleration of the building. w is the seismic weight of the building.

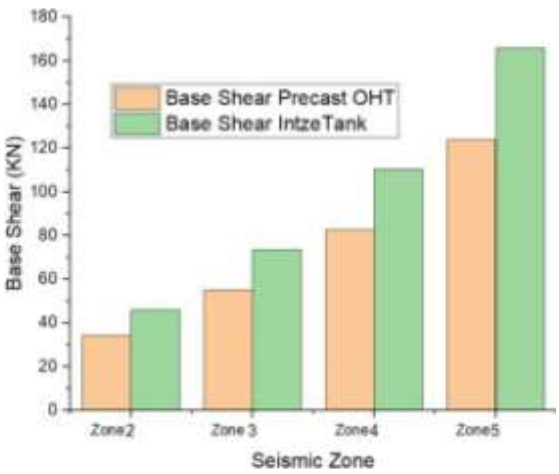

Fig. 9 Graph For Base Shear In Various Zones

As we move from lower seismic zones (Zone 2) to higher seismic zones (Zone 5), the base shear for the Intze Tank increases significantly. This is expected because structures in higher seismic zones are subjected to stronger ground shaking.

The Intze Tank appears to be designed to withstand seismic forces, as the base shear values are within acceptable limits for the specified seismic zones. Similar to the Intze Tank, the base shear for the Precast OHT also increases as we move to higher seismic zones. This is consistent with seismic design principles.

The Intze tank appears to have a higher base shear compared to the Precast Tank in all seismic zones. This indicates that the Precast OHT is designed to be more resistant and capable of withstanding stronger seismic forces.

Storey Displacement

In seismic design, storey displacement is a critical parameter used to evaluate the lateral movement or drift of each floor level in a building during an earthquake. The assessment of story displacement helps engineers understand how much lateral deformation or movement each floor experiences relative to the ground.

In accordance with IS 1893:2016 "Criteria for Earthquake Resistant Design of Structures," the story displacement is calculated based on the seismic zone, importance factor, and response reduction factor. Designing for permissible storey displacements helps prevent structural damage, minimizes non-structural damages, and ensures the safety of building occupants during seismic events.

The max displacement from the code IS 1893:2016, the limit of dis- placement for the structure is H/250.

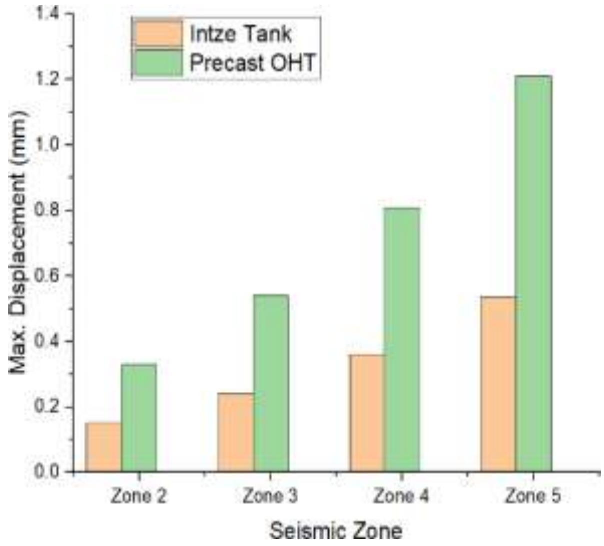

Fig.10 Graph showing max. displacement for various seismic zones

These values represent the amount of movement or deformation ex- perienced by specific nodes or points within the Intze tank structure during a particular event, like an earthquake or other dynamic loads. This value represents the maximum displacement experienced by Node 886 in the precast OHT and maximum displacement experienced by Node 1168 in the Intze tank.

Comparison between different zones for Intze Tank and Precast Over- head tank. In Zone 2, the Precast OHT has approximately 45% higher storey dis- placement than the Intze Tank. In Zone 3, the Precast OHT has ap- proximately 50% higher storey displacement than the Intze Tank. In Zone 4, the Precast OHT has approximately 54% higher storey dis- placement than the Intze Tank. In Zone 5, the Precast OHT has ap- proximately 55% higher storey displacement than the Intze Tank.

Percentage increase in maximum displacement for Precast overhead tank.

From zone 2 to zone 3 increased by 63%, zone 3 to zone 4 increased by 33.4% increase and from zone 4 to zone 5 increased by 33%. Per- centage increase in maximum displacement for Intze tank.

Zone 2 to 3 increased by 37.5%, zone 3 to 4 increased by 30.5% and from zone 4 to zone 5 increased by 33.3%. This suggests that the Intze is less susceptible to deformation during the same event or conditions as the Intze tank.

The displacement values are highest at zone 5 for both precast OHT and Intze tank. So, at the lower zones the value of maximum displacement is comparatively less and highest at zone 5. The displacement increases for both precast OHT and Intze tank as we move to higher zones.

Storey Stiffness parameters

Story stiffness, also known as lateral stiffness or lateral rigidity, refers to the resistance of a structure’s individual floors to lateral or horizon- tal displacements caused by lateral loads such as wind or seismic forces. It is an essential parameter in structural engineering and seis- mic design, as it directly influences the building's response to lateral loads and its overall structural behavior.

It involves evaluating the rel- ative stiffness of different levels or stories within a building to ensure its overall stability and proper response to various loads and environ- mental forces.

Higher story stiffness is desirable in structures located in seismic- prone regions, as it helps to reduce story drifts and better distribute lateral forces through the building. This, in turn, minimizes damage and enhances the building's seismic performance.

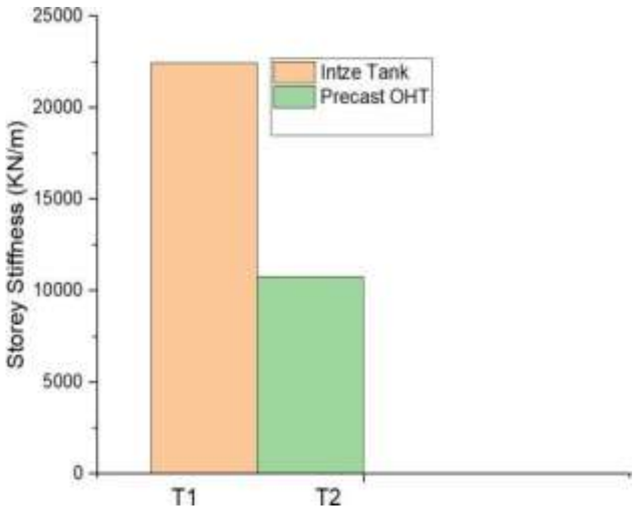

Fig.11 Storey Stiffness at different levels (m)

Storey stiffness is a critical structural parameter that measures the resistance of a building or structure to lateral displacements, such as those caused by wind or seismic forces.

The percentage change indicates that the storey stiffness of the Precast OHT is approximately 52% lower than that of the Intze Tank. In other words, the Intze Tank has a significantly higher storey stiffness com- pared to the Precast OHT.

CONCLUSIONS

From the above graphs, it is clear that Precast OHT give better results than Intze tank. The results are in agreement with the study carried out that Precast OHT has better performance against seismic parameters. Following inferences can be made from the results above.

As the seismic zones increase from zone 2 to zone 5 the values of base shear also increase. As seismic intensity increase, base shear values increase from zone II to V for both Intze tank and precast OHT because base shear directly depend upon zone factor(Z). Zone factor value for seismic zone V (0.36) is maximum. The base shear of Intze tank is higher when compared with precast OHT in all zones.

In summary, the structure with the lower base shear value
(precast tank) is more resistant to seismic forces and is generally considered more stable during an earthquake than the structure with the higher base shear value (Intze tank).

The displacement increases for both precast OHT and Intze tank as we move to higher zones. At the lower zones the value of maximum deflection is comparatively less and high- est at zone 5.

- In each seismic zone, the Precast Tank has a significantly higher maximum displacement compared to the Intze Tank.
- The percentage difference between the two tanks ranges from approximately to 50% to 55.45% across different seis- mic zones.
- The results suggest that in all seismic zones (Zone 2, Zone 3, Zone 4, and Zone 5), the Precast Tank experiences a significantly higher level of displacement in comparison with Intze tank.
- The percentage change indicates that the storey stiffness of the Precast OHT is approximately 52% lower than that of the Intze Tank
- These differences in stiffness reflect the specific design and functional requirements of each structure, as well as the seis- mic and environmental considerations.

REFERENCES

[1]. Latha, M.S., 2021. Comparison of Analysis between Rectangular and Circular Overhead Water Tank. Applied Research on Civil Engineering and Environment, 2, pp.77-95.
[2]. Nidhi, A.B., Study of Intze Tank with Different Horizontal Bracing Patterns.
[3]. Tripathi, S.S. and Thapa, K.B., 2021. Seismic Performance of Elevated Reinforced Concrete Water Tanks. Journal of the Institute of Engineering, 16(1).

[4]. Imadabathuni, Chandana, Padala Sri Vardhan Goud, Nalla Ravi Kiran, and Bathula Naveen. "Analysis and Design of Intze Water Tank by Using STAAD Pro." In E3S Web of Conferences, vol. 309, p. 01178. EDP Sciences, 2021.

[5]. Titiksh, A., 2019. Parametric study on cylindrical water tanks by varying their aspect ratios. Asian Journal of Civil Engineering, 20(2), pp.187-196.

[6]. Sambary, Pradnya V., and D. M. Joshi. "Seismic analysis of RC elevated water tanks." International Journal of Scientific & Engineering Research 6 (2015): 247- 252.[13] Jerath, S. and Lee, M., 2015. Stability analysis of cylindrical tanks under static and earthquake loading. Journal of Civil Engineering and Architecture, 9(1), pp.72-79.

[7]. Krishna Rao, M.V. and Kumar, R., 2015. P, Divya Dhatri. K.(2015).“Seismic Analysis of Overhead Circular Water Tanks–A Comparative Study”. International Journal of Research in Engineering and Technology (IJRET), 4(01).

[8]. Saroja, P.L.N. and Rao, V.S., 2016. Comparative Study of Seismic Analysis of Existing Elevated Reinforced Concrete Intze Water Tank Supported on Frame Staging. Int. J. Constr. Res. Civ. Eng, 2(1), pp.10-21.[8] Mir, F.U.H., Yu, C.C. and

[9]. Whittaker, A.S., 2021. Experimental and numerical studies of seismic fluid- structure interaction in a base-supported cylindrical vessel. Earthquake Engineering & Structural Dynamics, 50(5), pp.1395-14

[10]. Harsha, K., Reddy, K.K.K. and Kala, K.S., 2015. Seismic Analysis and Design of INTZE Type Water Tank. International Journal of Science Technology and Engineering, ISSN.

[11]. Tirupathi, D. and Srinivasu, K., Comparison of Elevated Water Tank Designs in Different Seismic Zones.