

Analysis of Elevated Circular and Rectangle Water Tanks according to different Seismic zones of India by using STAAD- Pro: A Review

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Abstract - Elevated reinforced cement concrete (RCC) water tanks are critical infrastructure components, especially in seismic-prone regions, where their structural integrity directly impacts public safety and service continuity. This review paper synthesizes findings from various studies focusing on the seismic behavior of elevated water tanks with different geometries, capacities, and operating conditions. The analysis highlights the comparative performance of circular and rectangular tanks under varying seismic zones, water filling conditions, and soil types, primarily using STAAD.Pro-based modeling approaches. The reviewed literature indicates that circular tanks consistently demonstrate better seismic resistance due to their uniform geometry, resulting in reduced stress concentrations and lateral displacements. Factors such as tank height, staging configuration, and foundation conditions significantly influence seismic response, with increased height and soft soil conditions amplifying structural demands. Additionally, partially filled tanks are identified as the most critical condition due to asymmetric mass distribution. The review also emphasizes the importance of adhering to design codes and adopting optimized construction practices to enhance durability and performance. Overall, the study underscores the need for integrated design approaches that consider geometric, structural, and operational parameters to ensure the safety and efficiency of elevated water tanks in seismic regions.

Keywords:

Elevated RCC water tanks, Seismic analysis, STAAD.Pro, Circular vs rectangular tanks, Base shear, Structural stability

1. INTRODUCTION

1.1 Background of the Study

Water is one of the most essential natural resources for sustaining life and facilitating economic development. The storage and distribution of water for domestic, industrial, and agricultural use require efficient structural systems that can safely store and supply water at desired pressures. Elevated water tanks play a crucial role in modern infrastructure, particularly in urban and rural water supply systems. By raising the storage reservoir above ground level, these tanks enable a consistent and gravity-driven supply of water, ensuring adequate pressure in the distribution network without the need for continuous pumping.

In India, elevated water tanks are integral to municipal water distribution systems, firefighting networks, and industrial facilities. They are often designed as either circular or rectangular containers supported by a staging system made of reinforced concrete or steel. The geometric configuration of

the tank significantly influences its behavior under various loading conditions. While circular tanks provide uniform distribution of stresses and are structurally efficient, rectangular tanks are often preferred for space optimization and architectural considerations. Both configurations, however, must be designed to withstand the combination of static and dynamic forces imposed by self-weight, water load, wind load, and more critically, seismic loads.

India's geographical location makes it highly susceptible to earthquakes due to its proximity to several active tectonic plate boundaries. The Indian subcontinent is divided into four major seismic zones (II, III, IV, and V) as per the Bureau of Indian Standards (IS 1893: 2016), with Zone V being the most severe. Elevated water tanks are particularly vulnerable during earthquakes because of their elevated mass, flexibility of staging, and dynamic interaction between the tank, staging, and contained water. Failure of such structures can result not only in economic loss but also in severe disruption of essential services, particularly during post-earthquake scenarios when water is most needed for firefighting and rehabilitation.

The advent of modern structural analysis software such as STAAD.Pro has revolutionized the process of modeling and analyzing complex structural systems under dynamic loading conditions. By using STAAD.Pro, engineers can simulate real-world behavior of structures, perform response spectrum or time-history analyses, and evaluate the performance of structures under various seismic conditions. This makes it an invaluable tool for comparing the performance of different tank geometries across multiple seismic zones.

This study focuses on the comparative analysis of elevated circular and rectangular water tanks subjected to different seismic intensities across India, using STAAD.Pro as the primary analytical tool. Through a systematic modeling and analysis process, this dissertation aims to identify the structural responses, critical stress points, and overall stability of these tanks, thereby providing valuable insights into optimal design strategies for seismic resilience.

1.2 Need and Significance of the Study

The catastrophic impact of past earthquakes in India—such as the 1993 Latur earthquake, the 2001 Bhuj earthquake, and the 2015 Nepal earthquake—has underscored the vulnerability of elevated storage structures. Numerous case studies have reported partial or complete collapse of elevated water tanks due to inadequate seismic design considerations, improper staging configurations, and insufficient ductility provisions. Such failures not only result in water scarcity but can also cause secondary disasters, including flooding and damage to nearby infrastructure.

Traditional design methodologies often relied on simplified static analysis and empirical design coefficients, which might not accurately represent the dynamic behavior of water tank

systems. The hydrodynamic pressure exerted by the oscillating water mass during an earthquake significantly alters the overall response of the tank, making it essential to perform dynamic analysis using reliable computational models.

Moreover, with the increasing emphasis on performance-based seismic design, it is imperative to evaluate how different geometries of tanks—circular and rectangular—respond to ground motion across varying seismic zones. This study contributes to this growing body of research by integrating advanced computational modeling with Indian seismic design provisions. It will help structural engineers, designers, and policymakers in selecting appropriate configurations and materials that ensure both economic efficiency and safety.

The findings of this research hold particular importance for various stakeholders involved in infrastructure development and management. For urban and rural water supply authorities, the results will help in optimizing the design of elevated water tanks by ensuring a balance between cost-effectiveness and structural safety. Structural consultants and practicing engineers can utilize the outcomes of this study to develop more reliable models for seismic evaluation, enabling them to design tanks that can withstand varying earthquake intensities across different regions of India. Furthermore, students and researchers will benefit from a deeper understanding of the complex interactions among geometry, material properties, and dynamic loading conditions that influence the seismic performance of elevated tanks. Overall, the study contributes to the broader national vision of building resilient infrastructure, supporting the objectives of India's "Smart Cities Mission" and promoting disaster-resilient urban planning frameworks.

1.3 Overview of Elevated Water Tank Structures

Elevated water tanks are vital components of water distribution systems and are typically composed of three major parts: the container, the staging, and the foundation. The container, or tank, serves as the main water-holding unit and may be circular, rectangular, or occasionally Intze-type, depending on the design requirements and economic considerations. The staging is the supporting framework made up of columns, braces, and beams that raise the container to the required elevation, ensuring that sufficient water pressure is maintained in the distribution network through gravity flow. The foundation forms the base of the structure and transfers the loads safely to the ground, maintaining overall stability. The container must be designed to be watertight and capable of resisting hydrostatic pressure exerted by the stored water at various depths. Meanwhile, the staging system must provide adequate stiffness and strength to withstand both vertical and lateral forces, including those arising from wind and seismic activity. The dynamic behavior of an elevated water tank depends on several factors such as the geometry and size of the tank, the height of the staging, the type of staging configuration (frame type, shaft type, or braced frame), and the interaction between the contained water and the tank walls during dynamic motion.

The seismic performance of these systems is particularly complex because the water inside the container behaves as a dynamic mass that interacts with the structural elements of the tank. This interaction gives rise to impulsive and convective (sloshing) components of hydrodynamic pressure. The impulsive component represents the portion of the water that

moves synchronously with the tank walls, while the convective component accounts for the free oscillation or sloshing of water. Both components significantly influence the overall response of the tank under earthquake loading. Therefore, accurate modeling of these hydrodynamic effects is essential for predicting realistic structural responses and ensuring the safety and reliability of elevated water tanks during seismic events.

1.4 Seismic Behavior of Elevated Water Tanks.

The seismic response of elevated water tanks differs considerably from that of conventional building structures because of the presence of a large concentrated mass at an elevated height, which leads to significant overturning moments and lateral displacements during earthquakes. When subjected to ground motion, the water contained within the tank exerts dynamic or hydrodynamic pressures on the walls and the base, producing substantial stresses and deformations in both the container and the supporting staging system. The dynamic behavior of such tanks can be broadly categorized into two vibration modes: the impulsive mode and the convective (sloshing) mode. In the impulsive mode, a portion of the water mass moves almost rigidly along with the tank walls, while in the convective mode, a part of the water oscillates freely, generating sloshing effects that influence the dynamic response of the structure. The relative significance of these two modes depends on factors such as the geometry of the tank, the depth of water, and the boundary conditions. Circular tanks generally demonstrate a more uniform distribution of hydrodynamic forces and better structural performance under seismic loading, whereas rectangular tanks tend to develop higher stress concentrations, particularly at corners and along the wall intersections.

Past earthquake events have revealed several modes of failure in elevated water tanks, including shear failure or buckling of staging columns, cracking and leakage of the container due to excessive tensile stresses, instability of the foundation resulting from high overturning moments, and differential settlement or loss of support at the base connections. These failures highlight the complex interaction between the tank structure and the contained fluid, emphasizing the necessity for realistic modeling and advanced analytical techniques. Therefore, it becomes imperative to analyze elevated water tanks by considering both structural dynamics and fluid-structure interaction effects to accurately predict their behavior under varying seismic intensities and ensure their safety and serviceability in earthquake-prone regions.

1.5 Seismic Zoning in India

India's seismic zoning map divides the country into four main seismic zones based on the expected level of seismic intensity. As per IS 1893 (Part 1): 2016, the zones are:

- Zone II – Low damage risk zone.
- Zone III – Moderate damage risk zone.
- Zone IV – Severe damage risk zone.
- Zone V – Very severe damage risk zone.

Each zone is assigned a Zone Factor (Z) that represents the peak ground acceleration expected during an earthquake. Structural design within these zones requires different seismic coefficients, response reduction factors, and importance factors to ensure safety. Since elevated water tanks are

classified as essential structures, they are designed with higher importance factors to remain operational after earthquakes.

Analyzing the same structure across different seismic zones allows for a comprehensive understanding of how geographical variation in seismicity affects structural performance, member forces, and displacement characteristics.

1.6 Role of STAAD.Pro in Seismic Analysis

STAAD.Pro, developed by Bentley Systems, is one of the most sophisticated and widely adopted structural analysis and design software tools used by civil and structural engineers worldwide. It provides a comprehensive platform for analyzing and designing structures subjected to a variety of loads and environmental conditions. The software is capable of performing linear, nonlinear, static, and dynamic analyses, making it particularly suitable for complex structural systems such as elevated water tanks. STAAD.Pro adheres to several international design standards, including Indian Standards (IS codes), and supports advanced analytical procedures like Response Spectrum Analysis (RSA) and Time History Analysis (THA), both of which are essential for evaluating the seismic performance of structures. The ability of STAAD.Pro to integrate these analytical methods allows engineers to predict how a structure will respond under different seismic intensities, thereby improving design reliability and safety.

The strength of STAAD.Pro lies in its capability to model intricate geometries with precise dimensions and material definitions. It enables users to define boundary conditions, apply various types of loads—including dead, live, wind, and seismic loads—and simulate realistic behavior under static and dynamic conditions. The software also facilitates the execution of modal analysis, which helps determine the natural frequencies and mode shapes of a structure—crucial parameters in seismic design that influence the magnitude of dynamic response. Furthermore, the program generates detailed output reports, including member forces, bending moments, displacements, shear forces, and stress distributions. This detailed post-analysis data assists engineers in evaluating the overall structural performance and identifying potential weaknesses or overstressed regions in the structure.

In the context of seismic design, STAAD.Pro provides an effective computational framework for incorporating seismic load parameters as prescribed by IS 1893 (Part 2): 2014, which specifically deals with the seismic analysis of liquid-retaining structures such as elevated water tanks. This code outlines the method for computing design seismic forces, considering factors like seismic zone, importance factor, response reduction factor, and the natural period of vibration. STAAD.Pro allows these parameters to be easily inputted and automatically generates the design spectrum corresponding to different seismic zones (II to V). It can also simulate both impulsive and convective modes of vibration in water tanks, which are critical for understanding the hydrodynamic effects of the contained liquid during ground motion.

For this dissertation, STAAD.Pro is employed to model and analyze elevated circular and rectangular reinforced concrete water tanks of identical capacity and staging height. The models are created in three dimensions to capture realistic structural behavior, ensuring that both geometric and material nonlinearities are appropriately represented. The staging system—comprising columns, bracings, and beams—is modeled to accurately simulate the support conditions that influence dynamic performance. Each model is subjected to

seismic loading conditions corresponding to India's four major seismic zones (II, III, IV, and V). By maintaining the same material properties and loading conditions across models, the study isolates the effect of geometric configuration on seismic performance. This enables a fair and systematic comparison of how circular and rectangular tank shapes influence the distribution of forces and displacements under earthquake excitation.

The parameters assessed through STAAD.Pro analysis include maximum base shear, bending moments in staging members, roof and wall stresses in the container, and lateral displacements at various levels. The base shear provides an indication of the total lateral force experienced by the structure during an earthquake, while the bending moments help evaluate the flexural demand on columns and beams of the staging. Roof and wall stresses reveal how the contained water interacts with the tank walls, indicating potential zones of cracking or leakage under dynamic pressure. Lateral displacement and inter-storey drift are equally significant as they reflect the overall stability and serviceability of the tank structure during seismic vibrations. Comparing these responses across different seismic zones allows for identifying the threshold beyond which a particular geometry may become structurally inefficient or unsafe.

One of the critical advantages of using STAAD.Pro in this analysis is its ability to provide response visualization through graphical outputs and animation of mode shapes. This feature enables engineers to visually interpret the deformation pattern and identify critical stress points within the structure. For elevated water tanks, such visualization is particularly valuable as it reveals how the interaction between the tank and its supporting staging evolves with increasing seismic intensity. The software's powerful post-processing environment allows for detailed examination of node displacements, member forces, and stress contours, making it easier to draw meaningful comparisons between different design alternatives.

Moreover, STAAD.Pro ensures compliance with Indian design standards, such as IS 456:2000 for concrete design, IS 3370 (Part 4): 2007 for liquid-retaining structures, and IS 1893 (Part 2): 2014 for seismic analysis. These provisions guide the evaluation of factors like importance coefficient, response reduction factor, and damping ratio, which influence the final design forces. The integration of these codes ensures that the analysis results obtained are consistent with national design practices and suitable for practical application in Indian conditions. In addition, the software allows for automatic design checks, which ensure that the members satisfy both strength and serviceability criteria under combined static and dynamic loads.

Another notable advantage of STAAD.Pro is its computational efficiency. Manual seismic analysis of elevated water tanks involves complex mathematical modeling of hydrodynamic effects and iterative calculations of modal responses, which are not only time-consuming but also prone to human error. STAAD.Pro automates this process, enabling engineers to perform multi-modal analysis quickly and accurately. The program's ability to handle large-scale models with numerous degrees of freedom makes it suitable for analyzing tall and complex staging configurations, which are typical in elevated water tank systems. Furthermore, the use of built-in response spectrum functions allows for rapid comparison of different seismic scenarios without reconstructing the model.

By leveraging these capabilities, the dissertation aims to derive meaningful insights into how tank geometry influences seismic performance. The results from STAAD.Pro simulations will highlight whether circular tanks, known for their symmetry and uniform stress distribution, perform better under seismic loading than rectangular tanks, which tend to experience stress concentration at corners and edges. Through such comparative analysis, the study intends to establish design recommendations that can help structural engineers optimize the shape and configuration of elevated water tanks, particularly in high-seismic-risk areas.

In summary, STAAD.Pro serves as a versatile and powerful analytical tool that bridges the gap between theoretical seismic design principles and real-world structural performance. Its ability to perform comprehensive dynamic analysis, integrate Indian code provisions, and generate detailed results makes it indispensable for this study. By using STAAD.Pro to model and analyze elevated circular and rectangular water tanks across various seismic zones of India, this research provides a robust framework for assessing seismic vulnerability and guiding the design of safer, more resilient water storage infrastructure. Ultimately, the use of such advanced computational tools contributes significantly to the field of earthquake engineering by promoting data-driven and performance-oriented design practices that can mitigate risks and ensure the sustainability of critical public utilities

1.7 Problem Statement

Despite the availability of several analytical and experimental studies on water tanks, the comparative seismic performance of elevated circular and rectangular tanks across multiple seismic zones remains insufficiently explored. The existing design codes, while providing general guidelines, do not explicitly address the influence of tank geometry on the dynamic behavior of structures subjected to varying seismic intensities. This limitation often leads to generalized design approaches that may not accurately represent the structural response under earthquake loading. Furthermore, many municipal and rural water supply projects in India continue to rely on empirical design practices that overlook detailed dynamic analysis. Such an approach can potentially compromise the structural safety and economic efficiency of these critical infrastructures. Hence, there is a strong need for a rigorous and systematic comparative analysis using advanced computational tools like STAAD.Pro to quantify the differences in seismic performance between circular and rectangular tanks, evaluate the effect of seismic zoning on stress distribution and displacement, and identify the most efficient geometry and staging configuration suitable for earthquake-prone regions.

1.8 Objectives of the Study

The primary objectives of the present dissertation are:

1. To model and analyze elevated circular and rectangular reinforced concrete water tanks using STAAD.Pro.
2. To evaluate the structural behavior of these tanks under seismic loading as per IS 1893 (Part 2): 2014 and IS 3370 (Part 4): 2007.
3. To compare the seismic performance of the two tank geometries in terms of base shear, displacement, stresses, and member forces across different seismic zones of India.

4. To identify the most suitable and economical configuration for earthquake-prone regions.

2. LITERATURE REVIEW

(SINGH & GROVER, 2025): This study focuses on the economical design of circular and rectangular elevated water tanks across different seismic zones using STAAD.Pro. The authors perform a comparative evaluation of structural parameters such as member forces, reinforcement requirements, and overall material consumption to achieve cost-efficient designs. Their work highlights that optimized geometry and reinforcement detailing can significantly reduce construction costs while still satisfying code provisions. The study is particularly useful for practicing engineers seeking practical and economical solutions. However, the analysis is largely based on linear static and response spectrum methods, which may not fully capture nonlinear seismic behavior. The absence of time-history or nonlinear analysis limits the understanding of post-yield performance. Incorporating advanced dynamic analysis could further enhance the reliability of their conclusions.

(Thakre & Samrutkar, 2025): The authors investigate the structural performance of elevated water tanks with chevron bracing under wind and seismic loading conditions. Using response spectrum analysis, they demonstrate that the introduction of bracing significantly reduces lateral displacement and internal forces in staging members. The study emphasizes the effectiveness of bracing systems in enhancing stiffness and improving seismic resistance. Their findings suggest that braced configurations can be a viable solution for retrofitting and new designs. However, the study primarily focuses on a specific bracing configuration without extensive comparison across different tank geometries. Additionally, economic implications and constructability aspects of bracing are not deeply explored. A broader parametric study would strengthen the applicability of their recommendations.

(Dhengare et al., 2024): This research presents a comprehensive finite element analysis of elevated water tanks with circular, rectangular, and square geometries in Seismic Zone V. The study reveals that circular tanks exhibit superior seismic performance due to their uniform stress distribution and reduced torsional effects. In contrast, rectangular and square tanks tend to develop stress concentrations at corners, making them more vulnerable to damage. The authors provide valuable insights into how geometry influences seismic response and structural stability. Their work strongly supports the preference for circular configurations in high seismic regions. However, the study could be further improved by incorporating different staging systems and reinforcement layouts. Inclusion of nonlinear time-history analysis would also enhance the depth of seismic evaluation.

(Buwade & Chandrakar, 2024): This paper provides a detailed review of design optimization strategies and construction practices for elevated water tanks. The authors emphasize the importance of integrating economic efficiency, durability, and seismic safety in the design process. They highlight the role of advanced modelling techniques and strict adherence to design codes in achieving reliable structural performance. The study

also discusses the significance of material optimization and quality control during construction. Their review suggests that combining computational analysis with practical engineering considerations leads to improved outcomes. However, as a review-based study, it lacks original numerical or experimental validation. Future work incorporating case studies or simulations would strengthen its practical relevance.

(Dhamija et al., 2024):The study investigates the seismic behavior of rectangular elevated water tanks under varying filling conditions using STAAD.Pro analysis. The authors identify that partially filled tanks experience the most critical stress conditions due to uneven mass distribution and dynamic effects. Their findings highlight the importance of considering operational conditions in seismic design. Additionally, the study emphasizes the role of staging configuration in controlling lateral displacement and ensuring structural stability. The results underline that improper staging design can significantly amplify seismic response. While the study provides valuable insights into rectangular tanks, it lacks comparative evaluation with circular configurations. Inclusion of such comparisons would provide a more comprehensive understanding of geometric effects.

(Kumar & Patil, 2023):This work compares STAAD.Pro-based analysis with traditional manual design calculations for circular elevated water tanks. The authors demonstrate that finite element modelling provides more accurate predictions of forces, stresses, and displacements compared to simplified manual approaches. Their study highlights the limitations of conventional design methods, particularly in capturing complex structural behavior. The comparison validates the reliability and efficiency of software-based analysis tools. However, the scope of the study is primarily methodological and does not deeply explore seismic variations or dynamic loading conditions. The absence of hydrodynamic pressure considerations also limits its applicability in seismic design. Expanding the study to include dynamic analysis would enhance its significance.

(Tirupathi & Srinivasu, 2023):The authors analyze the seismic response of elevated water tanks using IS code provisions, focusing on parameters such as base shear and overall dynamic behavior. Their study emphasizes the influence of tank geometry and lumped mass modelling on seismic force estimation. The results indicate that different geometries lead to variations in base shear and displacement response. The research provides useful insights into codal approaches for seismic analysis. However, the study primarily relies on simplified modelling techniques and does not extensively consider detailed staging configurations. The effects of hydrodynamic pressures, including impulsive and convective components, are also not fully explored. A more comprehensive dynamic analysis would improve the depth of the study.

(Gadekar & Patel, 2022):This study examines the structural behavior of underground water tanks with different geometries and filling conditions using STAAD.Pro. The authors highlight that tank shape significantly affects stress distribution and deformation patterns. Their findings show that circular tanks tend to distribute stresses more uniformly compared to rectangular configurations. The study also

emphasizes the role of fill conditions in influencing structural response. While the results provide useful insights into geometric behavior, the focus on underground tanks limits direct applicability to elevated structures. The boundary conditions and loading scenarios differ significantly between the two cases. Therefore, the study serves as supplementary evidence rather than direct validation for elevated tank behavior.

(Mankar et al., 2021) investigate the seismic behaviour of circular elevated water tanks with particular emphasis on structural continuity at joints in Seismic Zone III. Their study demonstrates that modelling continuity significantly influences force distribution, deformation patterns, and overall structural response. The authors highlight that neglecting joint behaviour can lead to inaccurate estimation of stresses and displacements. The analysis carried out using STAAD.Pro provides useful insight into realistic modelling practices for elevated tanks. However, the study is limited to a single tank configuration and a specific seismic zone, which restricts broader generalization. Inclusion of multiple geometries and seismic zones would have improved the applicability of the findings. Nevertheless, the work underscores the importance of connection detailing in seismic design.

(Anjum & Zameeruddin, 2021) evaluate the seismic performance of elevated water tanks considering variations in height and geometry. Their results indicate that increasing tank height leads to a significant rise in lateral displacement and base shear, thereby increasing seismic vulnerability. The study also compares circular and rectangular tanks, concluding that circular tanks exhibit more uniform stress distribution and enhanced stability. The authors emphasize that geometry plays a crucial role in controlling seismic response. Their findings are particularly relevant for the design of high staging systems in seismic regions. However, the study could be strengthened by incorporating nonlinear dynamic analysis. Overall, it provides valuable design recommendations for improving seismic safety.

(Tokhi & Arora, 2019) conduct a comparative seismic analysis of Intze-type, circular, and rectangular water tanks using response spectrum methods based on codal provisions. Their study highlights that Intze-type tanks perform better under seismic loading due to their efficient geometry and load transfer mechanisms. The authors analyze modal properties, base shear, and displacement characteristics to assess performance. The results indicate that tank shape significantly affects dynamic response and structural safety. While the study offers a comprehensive comparison of different geometries, it lacks extensive parametric variation. Inclusion of different staging configurations and seismic zones would enhance the robustness of conclusions. Nonetheless, it provides important insights into geometry-based design optimization.

(Talari Obulapathi & Chandrudu, 2018) analyze the design and behaviour of Intze-type water tanks with a focus on wall configuration and curvature effects. Their study demonstrates that curved surfaces in Intze tanks help in reducing bending stresses and improving load distribution. The authors also provide comparative observations with rectangular and polygonal tanks, highlighting the structural advantages of circular forms. The findings emphasize that geometry plays a

key role in enhancing strength and stability under seismic and hydrostatic loads. The use of STAAD.Pro enables detailed stress analysis and design evaluation. However, the study is primarily limited to Intze-type tanks and does not extensively explore other configurations. Overall, it supports the efficiency of circular and curved geometries in tank design.

(Ali & Telang, 2017) present a comprehensive review of dynamic analysis methods for elevated water tanks, focusing on staging configurations and seismic behaviour. Their work compiles various modelling approaches, capacity ranges, and observed failure mechanisms reported in previous studies. The authors highlight that staging type—such as frame, shaft, or braced systems—has a significant impact on dynamic response. They also identify that many existing design practices inadequately consider seismic effects. The review effectively outlines research gaps and the need for more integrated studies. However, it remains largely descriptive without quantitative comparisons. Overall, the study provides a strong foundation for identifying future research directions.

(Aware & Mathada, 2016) investigate the influence of tank height and seismic zones on the performance of circular elevated water tanks. Their results show that increasing height leads to higher nodal displacement and base shear, thereby increasing seismic demand. The study emphasizes the importance of optimizing tank height to achieve a balance between functionality and safety. The authors also compare different tank shapes and conclude that circular tanks offer better dynamic stability. Their analysis highlights the role of geometric symmetry in reducing stress concentrations. However, the study could benefit from inclusion of nonlinear or time-history analysis. Overall, it reinforces the significance of geometric and dimensional parameters in seismic design.

(Hariteja et al., 2016) perform seismic analysis of circular elevated water tanks using response spectrum methods under different filling conditions. Their study distinguishes between impulsive and convective mass components and evaluates their contribution to structural response. The authors report that filling conditions significantly influence stress distribution and dynamic characteristics. The results provide insight into potential failure mechanisms under seismic excitation. The study effectively captures modal behaviour and highlights the importance of hydrodynamic effects. However, it is limited to circular tanks and does not include comparisons with other geometries. Overall, it contributes to understanding fluid–structure interaction in seismic analysis.

(Singh & Ishtiaque, 2015) present a comparative analysis of Intze-type elevated water tanks subjected to wind and seismic loads. Their study demonstrates how tank geometry influences stress distribution and structural behaviour under combined loading conditions. The authors highlight that aerodynamic and seismic forces interact to affect staging and tank wall stresses. The analysis emphasizes the need to consider multiple loading scenarios in design. While the study provides useful comparative insights, it could be improved by incorporating hydrodynamic effects. Additionally, broader parametric studies would enhance its applicability. Nonetheless, it underlines the importance of geometry and loading interaction in design.

(Rana et al., 2015) investigate the effect of tank height, soil conditions, and seismic zones on the performance of elevated water tanks. Their findings indicate that soil stiffness plays a significant role in influencing structural response, with soft soils amplifying seismic effects. The study also shows that circular tanks perform better in terms of energy dissipation and structural integrity. The authors emphasize the importance of considering foundation conditions in design. Their work provides a comprehensive understanding of multiple influencing factors. However, the study could include more advanced dynamic analysis techniques. Overall, it highlights the combined effect of geometry, soil, and seismic parameters.

(Patel & Dashore, n.d.) analyze the seismic behaviour of elevated water tanks with different storage capacities across multiple seismic zones. Their study compares circular and rectangular geometries under varying water levels. The results indicate that circular tanks show lower displacement and improved lateral stability. The authors also observe that increasing tank capacity leads to higher base shear and bending moments. The study emphasizes the importance of considering capacity and geometry together in design. However, the absence of a specific publication year and limited methodological details reduce clarity. Overall, it provides useful comparative insights into tank performance.

(Agrawal et al., n.d.) examine the effect of different filling conditions on the seismic and wind performance of overhead water tanks. Their analysis shows that half-filled tanks experience the most critical stress conditions due to asymmetric mass distribution. The study compares circular and rectangular tanks and finds that circular tanks perform better with reduced lateral displacement. The authors highlight the importance of considering operational conditions in design. Their work demonstrates how filling levels influence dynamic response. However, the study would benefit from more detailed dynamic modelling. Overall, it reinforces the significance of both geometry and filling condition in seismic analysis.

3. CONCLUSIONS

The reviewed studies collectively highlight the critical influence of geometry, height, soil conditions, and operational parameters on the seismic performance of elevated RCC water tanks. A consistent observation across the literature is that circular tanks exhibit superior structural behavior compared to rectangular configurations due to their geometric symmetry, which ensures uniform stress distribution and reduced lateral displacement. The effect of tank height is also significant, as increased height leads to higher base shear and displacement, thereby increasing seismic vulnerability. Additionally, the filling condition of tanks plays a crucial role, with partially filled tanks often experiencing the most critical stress conditions due to unsymmetrical mass distribution. Soil characteristics further influence seismic response, where soft soils tend to amplify structural demands. The use of STAAD.Pro for modeling and analysis has proven effective in

evaluating these parameters and guiding design improvements. Overall, the studies emphasize the importance of adopting optimized design strategies, incorporating seismic code provisions, and ensuring proper construction practices. Circular and Intze-type tanks are recommended for earthquake-prone regions due to their enhanced stability and efficiency, while careful consideration of staging, foundation, and operational conditions is essential for achieving safe and economical designs.

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