

Analysis of Different Water Tanks: A Review

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Abstract- *The tanks are used to hold water, which is subsequently dispersed via public water supply systems. Built at a certain height, water tanks are referred to as "overhead water tanks" (OWT) or "elevated water tanks" (EWT). Many uneven topographies can also change the extent of seismic-induced damage to surface structures, and soils with varying stiffness can influence the seismic response characteristics of surface structures, according to recent study on seismic analysis of structures. Liquid storage tanks' seismic sensitivity can be studied to reduce the possibility of earthquake damage to these important buildings.*

Analysing the conventional, braced (diagonal and cross), and shell-stagging EWT for seismic load is the aim of the current work. Conventional, braced (diagonal and cross), and shell-stagging elevated Intze tanks have all had their lateral displacement and base shear examined and compared for that reason. Comparing lateral displacement and base shear, the current study showed that EWT outperformed traditional EWT.

Keywords- Intze Tank, Conventional Bracing, Shell Stagging, Base Shear, Lateral Displacement.

I. INTRODUCTION

Water is essential to human existence. A water tank's design at a particular location determines how well water is distributed. A huge water storage container designed to hold water supplies at a specific height in order to pressurise the water distribution system is called an elevated water tank. Water and other liquid materials can now be stored in a variety of ways thanks to numerous innovative concepts. Liquids can be stored in a variety of ways, including raised, ground-supported, and underground. Water, flammable liquids, and other chemicals are frequently stored in liquid storage tanks by businesses and municipalities. Water tanks are therefore crucial for both industrial and public utilities.

The significance of the water tank supporting system is discussed in this study, where it is seen as a distinct kind of bracing and layout. The study found that the diamond bracing pattern may be employed to provide a better supporting system lumped mass model and two mass model techniques

under high seismic force danger. The following characteristics of the draft code IS: 1893 (Part-2) recommendations show that elevated water tanks with frame type of staging operate better than those with previous guidelines, according to the assessments. and came to the conclusion that the total base shear and base moment measured under full tank conditions are 47% and 51% higher, respectively, than under empty tank conditions. As a result, tank full condition will dictate design. Seismic analysis takes into account the tank full scenario since there is more lateral force in the tank full state than in the tank empty state. A 36% increase in base shear is observed when comparing the lumped mass model technique with the two mass models. The maximum load to which the tank is exposed and, consequently, critical is indicated by the maximum values of forces and moments that were acquired using STAAD Pro. STAAD Pro's critical member check also shows that the tank is stable under extreme stresses and moments.

II. LITERATURE REVIEW

Several research studies have rigorously examined the seismic performance of elevated water tanks, particularly focusing on the influence of various bracing systems on structural response under dynamic loading conditions. These investigations highlight the critical role of bracing configurations—such as conventional, diagonal, X-bracing, and shell staging systems—in enhancing lateral stability and minimizing seismic vulnerability. Researchers have employed analytical tools like STAAD.Pro, SAP2000, and ANSYS to conduct nonlinear time-history and response spectrum analyses, evaluating parameters such as base shear, storey drift, displacement, and overturning moments. The findings consistently indicate that bracing systems significantly alter seismic behavior, with X-bracing and shell staging tanks generally demonstrating superior performance in terms of reduced lateral displacement and drift. Diagonal bracing, though more economical, offers moderate seismic resistance, while conventional bracing tends to show higher deformation and base shear under strong ground motion. Recent studies also incorporate parametric analyses, assessing the effects of tank geometry, water mass fluctuation, and bracing stiffness. Furthermore, investigations underline the importance of staging height and soil-structure interaction in amplifying seismic responses.

REVIEW OF LITERATURE SURVEY

Jiaqi Ren et.al (2024) examined, using the finite element numerical modelling method, the seismic response characteristics of eighteen models of liquid storage tanks. Nine earthquake records were taken into consideration, along with two different topographical types, three different tank sizes, and three different liquid heights. Calculations and presentations of the base shear force, normal stress in the tank wall, shear stress in the tank bottom, and maximum displacement of the tank wall were made using finite element models.

The value of normal stress in the tank wall was marginally higher in step-like slope topography than in level topography. Similar results were obtained for the displacement of the tank wall and the shear stress in the tank bottom. The average increase for normal stress in the tank wall was between 4.38% and 67.18%. The range of the average increase in shear stress under seismic excitations was 5.19% to 67.36%. Similarly, the average displacement increase of the tanks' walls varied between 23.84% and 48.69%. Based on the results, the base shear force of the tanks was strongly impacted by the step-like slope topography. When comparing tanks built on flat terrain, the average base shear forces increased by 337.80% to 415.36%. The biggest difference was between Square-F-3 and Square S-3, where the base shear increased from 147.11 kN to 758.15 kN; the smallest difference was between Slender-F-4 and Slender S-4, where the base shear increased from 302.13 kN to 1322.74 kN. In Eurocode 8, the analytical equation's base shear force values were marginally lower than those of the tanks built on flat terrain and those with fixed bases, according to a comparison between the analytical equation's results and the finite element approach. Nonetheless, finite element simulations yielded base shear forces for the step-like slope topography that were noticeably greater than Eurocode 8 values. Basically, the geography of the step-like slope made it more likely that liquid storage tanks would sustain damage from earthquakes.

Akshit Lamba and Dr. P.S. Charpe (2023) Analysing and designing a sizable R.C.C. water tank that would be susceptible to wind and seismic stresses was the goal. Tank simulation was carried out with STAAD Pro. Structural restrictions are confirmed utilising a hydrostatic loading for the tank's maximum capacity based on the overall design and study.

According to the results, the measured hoop and meridional stresses are within the acceptable limit. From seismic zone III to seismic zone V, base shear and moments grow progressively. Moreover, the height of sloshing waves

grows progressively from seismic zone III to V. When the tank is fully filled, the base shear and moment values are greater than when it is empty. The average yield strength of steel is over 200 MPa, while that of concrete ranges from about 2 to 10 MPa. Therefore, it can be assumed that the water tank is quite strong given its value of 1.61 MPa.

Chukesh Singh and Dr. A. K. Dwivedi (2023) Seismic zones III and IV were to be analysed using the standard, braced (diagonal and cross), and shell-staggering EWT. Specifically, the base shear and lateral displacement of conventional, braced (diagonal and cross), and shell-staggering elevated Intze tanks were examined and contrasted.

According to the results, Zone IV has a greater lateral displacement than Zone III for standard elevated intze tanks. Compared to diagonally braced and conventionally braced elevated intze tanks, it was shown that cross-braced elevated intze tanks produced reduced lateral displacement. Shell staging raised intze tanks have less lateral displacement than conventional, diagonally braced, and cross-braced elevated intze tanks in both zones, i.e., Zone III and IV, according to a comparison with other intze tanks. In both earthquake zones, the elevated intze tanks that are filled with water always have a greater lateral displacement than those that are empty. In the full tank situation, the results show that water has less lateral displacement and raises the increased intze tank's base shear (in all circumstances).

Hariram Rimal et.al (2023) examined the usual overhead water tanks in the Kathmandu Valley for earthquake susceptibility. The case study uses a representative reinforced concrete (RC) watertank in the Kathmandu Valley. Non-linear time history analysis of a finite element model of the structure is used to generate fragility functions that correspond to various damage states. Additionally, the impact of soil-structure and fluid-structure interactions on total fragility is examined.

Compared to half and empty reservoir conditions, the full reservoir condition is determined to be more sensitive. Particularly at higher damage states, we find that the soil structure interaction effect is extremely noticeable when fluid-structure interaction is held constant. As an illustration, the exceedance probabilities for extensive damage state for full reservoir condition are 89% and 82%, respectively, for soil structure interaction and no soil structure interaction at 1g. Under full reservoir conditions, the exceedance probabilities for the collapse damage state are 62% and 52%, respectively, for scenarios of soil structure interaction and those without. The exceedance probability for extensive damage states in the case of half reservoir condition are 73% and 65%,

respectively, for soil structure interaction and non-interaction. With and without soil structure interaction, the collapse damage state for the identical situation shows exceedance probabilities at 1 g of 42% and 32%, respectively. Likewise, the empty reservoir condition shows that the probability of a severe damage state exceeding 1 g is 58% for the scenario with soil structure interaction and 42% for the scenario without. With and without soil structure interaction at 1 g, the same tank shows exceedance probabilities of 28% and 15%, respectively, in the case of collapse damage condition. It is discovered that while the tank is empty, the rate at which the fragility of a flexible base construction deviates from that of a fixed base one with rising ground motion intensity is at its greatest.

Kavish R. Sapre and Hemant B. Dahake (2023) Comparing the strains that an earthquake produces on elevated water tanks in different seismic zones while looking at a rectangular elevated water tank was the goal. Civil engineers consider cost, aseptic considerations, the intended usage, and the available materials while designing any construction. The impulsive and convective modes of an elevated water tank are studied using the code IS: 1893 (Part - 2): 2014, and the forces in the tank's full and empty states have also been considered. The seismic forces operating on raised water tanks are approximated for Zones II to IV based on this study, which also compared the base shear and base moment values for these zones.

According to the results, base shear increases by 60–150% when seismic zones move from Zone II to Zone IV, accounting for hard rock in both filled and empty tanks. The hydrodynamic pressure on walls and base slabs rises between 45 and 145% when the seismic zone advances from Zone II to Zone IV, taking strong earthquakes into consideration. These findings are based on hard rock under full and empty tank conditions, and Base Moment increases between 50 and 150% as the seismic zone expands from Zone II to Zone IV.

G A Salman et.al (2022) Proposing a seismic reaction of an intze water tank for two distinct container shapes—the circular and hexagonal water tanks—was the goal, and the one with the best earthquake resistant behaviour was successfully accomplished. In accordance with Indian Standard 1893-2002 (Part 2), a dynamic analysis of elevated RCC water tank designs for zones III–V was conducted using the Staad.Pro program, taking into account all seismic forces.

According to the results, during seismic analysis, the zone factor, response reduction factor, and other factors cause the base shear of both full and empty water tanks to increase with seismic zones II–V. The absence of water or hydrostatic

pressure causes the base shear in a full tank to be slightly higher than in an empty tank. Seismic zones II–V result in greater displacement of both full and empty water tanks due to zone factors, response reduction factors, and other factors taken into account during seismic analysis. When the water tank is filled, the wall of the tank shows the maximum and minimum nodal displacements. When taking seismic analysis into consideration, the zone factor, response reduction factor, and other factors increase the shear force and bending moment of both full and empty water tanks in seismic zones II–V. Due to the lack of water or hydrostatic pressure, the shear force and bending moment in a full tank are somewhat greater than those in an empty tank. According to study, the RC circular water tank provides higher stiffness than the hexagonal water tank.

El-far et al. (2021) performed a comparison analysis comparing several seismic design codes and the response reduction factor for raised water tanks made of reinforced concrete. In this study, three distinct heights, capacity, and seismic zones were taken into consideration for raised tanks with two-column layouts (inclined and vertical). The response reduction factor values for raised water tanks as stated in IBC 2000, FEMA 368, ACI 350-3, AWWA-D100, Eurocode 8, IS 1893-2, and ECP 201 were compared in this study. The methodology that was selected was nonlinear static pushover analysis. The results showed that, in comparison to tanks with inclined columns, elevated water tanks with vertical columns typically had greater response reduction factor values. Furthermore, a decrease in the response reduction factor value was seen in all seismic zones as the tank height increased. The response reduction factor value, on the other hand, increased as the water tank's capacity increased.

Tayyaba Anjum and Mohd. Zameeruddin (2021) conducted a non-linear time history study on the models created using the data from the existent raised water tanks in the Nanded area of Maharashtra, India. Predicting the effectiveness of elevated water tanks was done using the engineering demand parameters that were collected.

According to the results, the structure's inherent frequency drops as water storage increases. The time frame changes depending on whether the tank is empty, half-full, or full. This results from the interaction of hydrodynamic pressure and sloshing. As the water level rises, base shear and base moment also rise. The base shear value rises in tandem with the seismic zone expansion. As the water level rises, so does the nodal displacement. Depending on the earthquake characteristics, the critical response of the elevated water tanks may occur even when the tank is half-filled or empty. It does not always happen when the tank is full.

Saudagar (2019) performed a comparative study of Intze and circular water tanks on sloping terrain. Response Spectrum Analysis was used in this study to examine the performance of two different kinds of elevated water tanks on various slopes. Different forms of staging arrangements, fluctuations in the ground slope, and constant water storage capacity and staging height are some of the characteristics that are considered in the analysis. Consequently, for full tank condition cases of 00-200 in seismic zone III, the circular tank's base shear and base moment are greater than those of the Intze type of tank. For seismic zone III slope situations of 00-200, the maximum displacement of the Intze type of tank is greater than that of the circular tank.

Liu (2018) considering about the seismic analysis and design of concrete tanks that hold liquid. Three categories of consideration were covered by the author in this study. First, they used the AWWA D115-06 and ACI 373 codes to consider the functions as a liquid-containing structure. Second, they took hydrodynamic seismic loads into account. Thirdly, they took into account seismic-related occurrences that are not covered by ACI standards, like tsunamis, soil foundation liquefaction, and floating raising of subterranean tanks. ACI 318.11 and ASCE 7 were followed in the design of the liquid-containing tanks, while ACI 350.3 was followed in the seismic analysis. The convective and impulsive components of hydrodynamic pressure distribution are linked to concrete walls by springs, in accordance with ACI 350.3. In order to ensure that concrete tanks are waterproof, resistant to cracking, and corrosion-free, this study was deemed crucial.

Tiwari (2018) used SAP2000 to conduct seismic analysis and research on the Intze tank design. Utilising SAP 2000, the author of this work performed a seismic analysis of an Intze tank, comparing the behaviour of shaft and frame staging types. While the seismic design was done in accordance with IS: 1893-2002, taking into account the conditions in Jabalpur, the tank was typically designed in accordance with IS: 3370(Part II) - 1965. Pushover behaviour, displacement behaviour in full water conditions, stress variation along the height, and base shear were all evaluated in order to complete the seismic study. A time period investigation was also carried out, and different combinations of loads were taken into consideration. According to the findings, frame staging took longer than shaft staging to complete.

A.C.Chougule et.al (2017) A parametric study on the spring mass model, time period in impulsive and convective mode, design horizontal seismic coefficient, base shear, and hydrodynamic pressure due to impulsive and convective mass of water were taken into consideration when conducting a

seismic analysis of the ground-supported water tank resting on soft soil.

Under the impact of seismic forces, the results showed that more water will excite in an impulsive mode as the ratio of the maximum depth of water to the tank diameter (h/D) increases, whereas more water will excite in a convective mode as the ratio decreases. Time periods in the convective and impulsive modes decrease when the h/d ratio rises and rises, respectively.

Srikanth S and Savithri Karanth (2017)"Time History Analysis of an Elevated Water Tank Under Different Ground Motions" was studied in order to understand the dynamic behaviour of elevated water tanks in conjunction with UG sump under various ground motion records from earthquakes. An elevated RCC square-shaped water storage tank with staging heights of 14 m, 17 m, and 20 m was subjected to Time History Analysis under five distinct seismic ground motions utilising FE-based Staad-Pro software. Roof displacement, velocity, acceleration, base shear, drift, and natural frequency were among the seismic reactions that were noted; as a result, the outcomes were compared under empty, half, and full tank water fill circumstances. The ground motion from the Kobe earthquake showed the least amount of seismic response, while the Bhuj earthquake showed the greatest.

Yazdani et al. (2017) investigated using the finite element method and fundamental frequencies of cylindrical storage tanks derived from codes. The seismic behaviour of storage tanks was investigated in this work, and convective and impulsive frequencies, among other factors, were compared using API 650 and Eurocode 8. Finite Element (FE) software and modal analysis were used in this work to get frequencies, which were then compared to analytical techniques from standards. In order to maintain comparability, tanks with varying (H/R) ratios were modelled using identical weight and capacity. The convective frequencies derived from the Finite Element approach and those from standards were found to be in good agreement. The results also demonstrated that convective and impulsive frequencies increased and decreased, respectively, as the liquid level increased. The impulsive frequency values also decreased by 17 percent when viscosity was increased by 1.47 times.

Kumar et al. (2016) examined the use of codal provisions in a comparative study of dynamic analysis approaches for rectangular liquid-filled containers. For rectangular-shaped tanks, the study carefully examined the seismic analysis methods described in IS 1893 Part 2, ACI 350.3, and Eurocode 8. One of the study's main conclusions was the various guidelines that the codes suggested for calculating the

system's overall response. Although ACI 350.3 and IS 1893 Part 2 recommended the square root-of-the-sum-of-the-squares (SRSS) rule, Eurocode 8 suggested using the absolute summation rule instead. The analysis also showed that in order to properly account for the mass of the tank wall, ACI 350.3 and Eurocode 8 recommended the inclusion of a reduction factor. As a result, it was discovered that the Impulsive time period using Eurocode 8 was greater than the Impulsive time period using ACI 350.3 and IS 1893 Part 2. In contrast, it was found that the Convective time period stayed largely constant throughout all three codes.

Atul Jadhav et al. (2015) In order to present the study of the seismic performance of the elevated water storage tanks for high-intensity seismic zones of India, he had examined and given the theoretical background of an article titled "A review paper on analysis of elevated water storage tank in a high seismic zone by using staad-pro software." He had done this for different sections of elevated water storage tanks for both flat and dome concrete floors. STAAD PRO software was used to show how the height of a water storage tank in seismic zones and the tank's section affected seismic forces. An elevated water storage tank's various portions within the high-intensity earthquake zone were compared, and the section that best fit the region's seismic activity was determined by the structure's behaviour. Additionally, researcher used STAAD PRO software to take into account the different forces acting on an elevated tank as well as different impacts, such as the sloshing effect.

Nathu D. Thombare et al. (2015) Using structural software, the study aimed to model the impulsive and convective water masses inside the container for various fluid conditions, bracing kinds, and bracing levels in order to determine the behaviour of the elevated water tank under discussion. The seismic performance of elevated water tanks was assessed for different heights and soil conditions as well as the effects of earthquake forces in different seismic zones of India.

The analysis and construction of raised water tanks against the effects of earthquakes are crucial, according to the conclusion. In the event of an earthquake, these structures must continue to operate. In particular, elevated water tanks are vulnerable to earthquake damage since they usually have a huge mass supported on top of a thin staging. Therefore, it is very important to analyse and design such structures to be earthquake-resistant.

F. Omidinasab and H. Shakib (2008) A 900-cube-meter sample of a reinforced concrete elevated water tank exposed to seven earthquake records was examined and analysed in dynamic time history as part of the study. The responses of the

tank, including base shear, overturning moment, tank displacement, and sloshing displacement, were calculated under these seven records, and the outcomes were then compared and contrasted.

An elevated tank's critical response does not always happen when it is fully filled; it can also happen when the tank is empty or just partially filled. Whether the system's responses are amplified or reduced relies on how well the frequency content and earthquake characteristics match. The responses of the structure for each record are therefore dependent on the earthquake characteristics and frequency content in addition to the dynamic aspects of the structure. According to nonlinear dynamic analysis, the joint between the supporting system and the container experiences the most displacement in the structure's height when taking the soil condition into account. The system's maximum displacement in stiff and moderately soft soils takes place where the supporting system joins the container, while in softer soils, it takes place at the roof level of the system. Higher stories are more susceptible than lower stories in nonlinear analysis. The system maximum displacement, which happens where the frame joins the tank's container, is the cause. The other explanation most likely has to do with how the main period of the structure differs from the tank's sloshing mode period.

III. CONCLUSION

The summary of the literature review showed that Seismic analysis of water tanks is an important area of research as water tanks are crucial structures that provide clean water to the community. In the literature review, it was found that most studies focused on rectangular and circular tanks supported by columns, which are commonly used in practice. The studies utilized various codes including IS (Indian Standards), ACI (American Concrete Institute), EN (European Norms), IBC2000 (International Building Code), and AWWA-D100 (American Water Works Association Standard). These codes provide guidelines for designing water tanks to withstand seismic forces. To conduct the analysis, researchers utilized different software programs such as STADD Pro, ETABS, and SAP2000. The analysis included the comparison of the resulting base shear, base moment, time period, and frequencies for both tank conditions. Comparing the results of the analysis for both tank conditions, the researchers found that circular tanks were generally more efficient in terms of resisting seismic loads than rectangular tanks. In short, the literature review revealed that seismic analysis of water tanks is a well-studied area, with various codes and software programs available to aid in the design process. The studies conducted focused mainly on rectangular and circular tanks supported by columns, with circular tanks

generally found to be more efficient in terms of resisting seismic loads.

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