International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 02 | Feb 2024 www.irjet.net p-ISSN: 2395-0072

The Seismic Behaviour of an Elevated Storage Reservoir Across Different Earthquake Regions

Akash Devidas Bobade[1], Dr. S. K. Patil [2], Dr. A. B. Pujari [3]

[1] *Post Graduate Student, Department of Civil Engineering, KJCOEMR, Pune, India*
[2] *Associate Professor, Department of Civil Engineering, KJCOEMR, Pune, India*
[3] *Associate Professor, Department of Civil Engineering, KJCOEMR, Pune, India*

---***---

Abstract - *Elevated water tanks play a crucial role in earthquake-prone regions, serving as vital structures that store liquids in containers situated at the top of supporting systems (staging). These structures are particularly susceptible to seismic forces during earthquakes, impacting essential functions such as water supply, fire-fighting systems, and industrial water storage. Damage to these tanks can lead to significant issues, including disruptions in drinking water supply and uncontrollable fires in industries dealing with flammable fluids. Maintaining the functionality of elevated water tanks post-earthquake is imperative. Consequently, extensive studies have been conducted to understand the seismic behaviour of these tanks under various conditions. In this investigation, we focus on analyzing tanks subjected to seismic forces, considering different seismic zones and container shapes (rectangular and circular) with a constant staging height. The analysis employs time history analysis, varying seismic zones, and tank shapes, specifically rectangular and circular. The study is conducted under empty tank conditions. Seismic forces acting on the tank are assessed using the Time history analysis method for earthquake zones 2 and 5, utilizing the ETABS software. Key seismic responses, including story displacement, story drift, time history analysis along the X-axis, and time history analysis along the Y-axis, are thoroughly evaluated and compared.*

Key words: Seismic forces, tank shape, Time history analysis, Earthquake zones, ETABS.

1. INTRODUCTION

The elevated water tank holds a crucial role in the water supply infrastructure, and its location significantly influences supply regulation. The topography also plays a vital role in the distribution system, with the elevated storage tank typically positioned at a higher point, often at the center of the distribution network. These tanks are supported by staging, typically consisting of RCC towers or columns with various bracing configurations.

In this project, the focus is on studying the impact of different seismic zones on different shapes of elevated storage tanks. The objective is to determine which tank shape exhibits greater resistance to seismic activity. The examination of various H/D ratios aims to understand the tank's strength in resisting seismic waves.

1.1Performance of elevated water tank

Geological and seismological discoveries during the 20thcentury have helped in initiating the development of seismic building codes and earthquake resistant buildings and structures. The improvement in seismic design requirements has led to more robust, safe and reliable buildings. Due to the earthquake many buildings collapsed killing thousands of people. Therefore, to protect the earthquake effects/earthquake damages to the buildings and to protect the life of people, it's important to use seismic control techniques.

1.2 Various analysis systems

1.2.1 Linear Static Analysis: Linear analysis methods give a good indication of the elastic capacity of the structures and indicate where first yielding will occur. The linear static method of analysis is limited to small, regular buildings.

1.2.2 Linear Response Spectrum Analysis: Linear response spectrum analysis is the most common types of analysis used. This is sufficient for almost all isolation system based on LRB and / or HDR bearings.

1.2.3 Non-Linear Static Analysis: In a nonlinear static analysis procedure, the building model incorporates directly the nonlinear force-deformation characteristics of individual's components and elements due to inelastic material response. The nonlinear force-deformation characteristics of the building are represented by a Pushover curve.

1.2.4 Linear Time History Analysis: Linear Time History Analysis provides little more information than the response spectrum analysis for a much greater degree of effort and is rarely used.

1.2.5 Nonlinear Time History Analysis: Nonlinear Time History Analysis can be used for all isolation systems regardless of height, size, geometry, location, and nonlinearity of the isolation system. Time-History analysis is a step-by-step procedure where the loading and the response history are evaluated at successive time increments. During each step, the response is evaluated from the initial conditions existing at the beginning of the step (displacements and velocities) and the loading history in the interval. Nonlinear time history analysis is the dynamic analysis in which the loading causes significant changes in stiffness. With this method, the non-linear behaviour may be easily considered by changing the structural properties (e.g., stiffness, (k) from one step to the next. Therefore, this method is one of the most effective for the solution of non- linear response. Non-linear time history analysis utilizes the combination of ground motion records with a detailed structural model, Response of base isolated structure on liquefiable soil.

Therefore, is capable of producing results with relatively low uncertainty. In nonlinear dynamic analyses, the detailed structural model subjected to a ground-motion record produces estimates of component deformations for each degree of freedom in the model and the modal responses are combined using schemes such as the square-root-sum-of- squares.

2. AIM

The project's goal is to analyze how elevated water tanks of various shapes, specifically circular and rectangular, respond to seismic activity in different earthquake-prone regions. This analysis will be conducted using the structural software ETABS.

3. OBJECTIVE

1. The primary aim of this project is to conduct a dynamic analysis of elevated water tanks using the time history analysis method.

2. The project seeks to assess key response parameters, including story displacement, drift, and stiffness.

3. An additional goal is to compare the seismic behaviour of water tanks with different shapes in zones II and V

4. FUTURE SCOPE

1.It can be studied for different capacities of water tank. Different types of foundation can be used to give different end conditions and hence a different analysis.

2.Comparison of shaft type staging with frame type staging will be done.

3.Optimization for best type of staging & design cross section of column and braces can be done.

4.Variation of H/D ratio of container can be studied for different zones.

5.Variation for number of columns with different staging heights at different zone can be studied.

6.Nonlinear analysis for Time history push over analysis can be done.

7.Different international codes with Indian codes can be compared for a rectangular arrangement of column with circular column can be studied

5. LITERATURE REVIEW

Mr. Raja Babu , Mr. R.C. Singh and Dr. Lokesh Singh(2019) Elevated water tanks are critical components of any urban planning scheme as they are commonly adopted by the municipal corporations to store the necessary water to meet the city's water demand. Experiences from past earthquakes have shown a strong indication that most of these structures are susceptible to damages related to earthquakes. One of the prime concerns for structural designers is the sloshing effects of the water stored in the tank. Sloshing basically refers to the movement of water contained in the overhead tank when subject to lateral motions occurring due to wind forces or earthquake excitations. The hydrodynamic forces and the overturning moments acting on the tank wall due to the impulsive component of the liquid motion can result in the failure of the tank wall and the tank foundation [1]. The spilling of the displaced water can also lead to damages to the tank roof.

Damini J. Dhondge, Dr. R. S. Talikoti (2019) Earthquakes are major calamities which have a potential to causing disturbance to infrastructure and lifeline facility. Water is basic needs for daily life. An elevated water tank is a large container built for the purpose of water supply it consists large water mass at the top of slender staging which is considering critical during an earthquake. For certain proportion of tank and structure, the sloshing of water during an earthquake is also a dominant factor. **Mr. Rohit Kiran Chaudhari, Dr. R. A. Dubal (2021)** Aim of this study is to bring out the differences in seismic behavior of column beam (Building) frame and column-brace (staging) frame in the post-elastic region and to quantify their ductility. In addition, nonlinear dynamic analysis is also carried to bring out the differences in the nonlinear dynamic behavior of without types of frames. Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is achieved. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the whole structure. A without or three-dimensional model which includes bilinear or tri-linear load-deformation diagrams of all lateral force resisting elements is first created and gravity loads are applied initially. **Sheetal Mohan Tarwatkar (2021)** The elevated water tank Supported on four number of columns in both rectangular tank as well as the circular tank. The height to depth ratio should not be exceed than 0.7. The two-parameter considered first one is height to depth ratio or height to length ratio in circular water tank and in rectangular water tank respectively is 0.87> 0.7 and 0.6< 0.7. To know which is better. **P Kodanda Rama Rao , S R K Reddy, AHL Swaroop and K Nagarjuna. 4(2021)** In this paper, two similar elevated R.C. circular water tanks, each of 4.0 lakh liters capacity supported by two types of foundations; one with circular ring raft below the columns of tank resting on sandy soils, and the other with circular ring raft supported by piles embedded in black cotton soils, are chosen for carrying out seismic analysis. In the analysis, the water tank is idealized as a system with three degrees of freedom, treating the staging of tank as one spring attached to the mass of the water tank and the soil is treated with two springs; one in horizontal and the other in rocking mode, both attached to the soil mass and the response parameters like; time periods, base shears and displacements are worked out against earthquake loads. Results indicate that, irrespective of type of foundation, the soil play important role on seismic response of elevated water tanks by virtue of their configuration with top heavy mass and slender staging; particularly displacements are found high when they rest on loose soils. According to the new guidelines provided in the revised IS 1893 (Part-1) 2016 code, SSI effect should be considered in seismic analysis when the structure rests on loose or soft soils. **Samruddhi Bulbule, Devica Mohite, Trupti Bomble, Dhanashree Bhujbal, Mr Uday Kakde5(2022)** In major cities and also in rural areas elevated water tanks forms an Integral part of water supply system. The elevated water tanks must remain functional even after the earthquakes as water tanks are most essential to provide water for drinking purpose. These structures has large mass concentrated at the top of slender which have Supporting structure. **Jayadeep K. S, Thejaswini R.M, L Govindaraju (2022)** In general, it lengthens, the apparent system period and increases the relative contribution of the rocking component of ground motion to the total response. In many cases, SSI is simply ignored in design without establishing whether it will increase or decrease the response of the structure. Further, soil conditions at a given site may amplify the response of a structure. By neglecting the amplification effect of the soil where the water tank is located may lead to a lead to an under-designed structure resulting in a premature collapse during an Earthquake.

6. METHODOLOGY

6.1 General

The main objective of this study is to examine the behaviour of overhead circular water tank supported on frame staging considering different modelling systems. All the above

Cases are analyzed for five different earthquake records i.e. time history analysis. The analysis is carried out using ETAB software.

Seismic Zones

Seismic zones in India are regions that are classified based on the likelihood of earthquakes occurring in the area. The classification of Seismic zones in India is done by the Bureau of Indian Standards (BIS), and other agencies are the European Mediterranean Seismological Centre (EMSC), and the United States Geological Survey (USGS) which help in determining the design and construction standards for buildings and structures in different parts of the country.

6.2 Earthquake Zones of India

The following is a summary of the four Seismic Zones of India:

Zone	Description
Zone 5	This zone includes areas that are highly susceptible to earthquakes and includes parts of the northwest, northeast, and the Andaman and Nicobar Islands. Buildings in this zone are required to be designed and constructed to withstand the highest level of seismic activity.
Zone 4	This zone includes areas that are moderately susceptible to earthquakes and includes parts of the Himalayan region, the western and eastern coasts, and parts of the central and southern regions of the country.
Zone 3	This zone includes areas that have a low to moderate level of seismic hazard and includes parts of the central and southern regions of the country.
Zone 2	This zone includes areas that have a very low level of seismic hazard and includes parts of the northeastern region of the country

7. MODELLING AND ANALYSIS

Introduction to ETAB

ETABS is an engineering software product that caters to multi-story building analysis and design. Modelling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS. For a sophisticated assessment of seismic performance, modal and direct-integration time-history analyses may couple with P-Delta and Large Displacement effects. Nonlinear links and concentrated PMM or fiber hinges may capture material nonlinearity under monotonic or hysteretic behaviour. Intuitive and integrated features make applications of any complexity practical to implement. Interoperability with a series of design and documentation platforms makes ETABS a coordinated and productive tool for designs which range from simple 2D frames to elaborate modern high-rises.

8. CONCLUTION

The circular elevated water tank demonstrates superior performance compared to the rectangular elevated water tank in both earthquake zones, namely Zone II and Zone V.

1. In terms of story displacement and drift, the circular tank exhibits lower values than the rectangular tank in both Zone II and Zone V.

2. Analyzing time history along the X-axis, the circular tank shows lower story stiffness and base shear compared to the rectangular tank in both seismic zones.

3. When considering time history along both X-axis and Y-axis, the circular tank in Zone II displays lower story displacement, drift, and base shear, with slightly higher maximum story stiffness compared to Zone V. On the other hand, the rectangular tank in Zone II shows lower story displacement, drift, maximum story stiffness, and base shear along the X-axis compared to Zone V.

4. Overall, the seismic analysis concludes that the circular elevated water tank outperforms the rectangular tank in both Zone II and Zone V. The circular tank exhibits better results in terms of story displacement, drift, stiffness, and base shear, indicating superior performance in seismic conditions.

REFRANCES-

1) Mr. Raja Babu , Mr. R.C. Singh and Dr. Lokesh Singh," Seismic Design Recommendations For Elevated Water Tanks " International Journal of Innovations in Engineering and Science, Vol. 4, No.9, 2019

2) Damini J. Dhondge, Dr. R. S. Talikoti ," Dynamic Analysis of Elevated Water Tanks" Electronic Journal of Structural Engineering 19(1) 2019

3) Mr. Rohit Kiran Chaudhari, Dr. R. A. Dubal," Non-Linear Time History Analysis of an Elevated Water Tank International Journal for Research in Applied Science & Engineering Technology (IJRASET) Volume 9 Issue VI June 2021

4) Sheetal Mohan Tarwatkar," Seismic Behaviour of Elevated RCC Water Tank Having Different H/D Ratio and Shape." International Journal of Engineering Research & Technology (IJERT) Vol. 10 Issue 08, August-2021

5) P Kodanda Rama Rao , S R K Reddy, AHL Swaroop and K Nagarjuna. 4," Seismic behaviour of existing elevated water tanks resting on different type of foundations." IOP Conf. Series: Earth and Environmental Science 982 (2022)

6) Samruddhi Bulbule, Devica Mohite, Trupti Bomble, Dhanashree Bhujbal, Mr Uday Kakde," A review Paper on Design on RCC ESR using ETABS and Comparing with Conventional Method." IJIRT Volume 8 Issue 9 February 2022

7) Jayadeep K. S, Thejaswini R.M, L Govindaraju," A study on the seismic response of elevated water tank" International Research Journal of Engineering and Technology (IRJET) Volume: 09 Issue: 03 | Mar 2022