E3S Web of Conferences **552**, 01131 (2024) https://doi.org/10.1051/e3sconf/202455201131
ICMPC 2024

Comparative Analysis of Various Bracing Configurations and Their Impact on Elevated Water Tank Performance

Jisha P K[1*], *Atul* Singla[2], *Voruganti* Sreevani[3], *Ravi* Shankar Raman[4], *Manoj* Kumar Vishkarma[5], *Ali* Albawi[6], *M* Ganesh[7]

[1]Department of Applied Science, New Horizon College of Engineering, Bangalore, India.
[2]Lovely Professional University, Phagwara, India.
[3]Department of CSBS, GRIET, Bachupally, Hyderabad, Telangana, India.
[4]Department of Mechanical Engineering, ABES Engineering College, Ghaziabad-201009, UP, India.
[5]Lloyd Institute of Engineering & Technology, Knowledge Park II, Greater Noida, Uttar Pradesh, India.
[6]Radiology Techniques Department, College of Medical Technology, The Islamic University, Najaf, Iraq
[7]Department of Aeronautical Engineering, MLR Institute of Technology, Hyderabad, Telangana, India-500085

Abstract. During a few extremely distressing earthquakes in India, R.C.C. elevated water tanks suffered significant damage or collapsed. This may have been brought on by incorrect staging geometry as well as ignorance of how the tank's supporting system should behave in the event of an earthquake. The elevated water tank is made up of structural components such as footings, beams, columns, and slabs. Subjected loads are passed between these components and ultimately to the soil's sub-grade. When an overhead tank is advantageously analysed, the elevated water tank behaves differently for distinct types of loadings (Dead, Live, and Seismic). Various combinations of loads that support the possibility of occurrence are indicated by the codes for Indian standards. The primary goal of this research is to improve performance during earthquakes and complement conventional staging by better understanding the behaviour of various bracing systems. Equivalent static analysis of various bracing system types applied to the elevated circular water tank staging in the seismic zone are carried out using STAAD Pro. The axial force and maximum bending moment of the circular water tank are examined in the X, Y, and Z axes. Several models are used to calculate the axial force and maximum bending moment for staging with cross bracing, diagonal bracing, and alternating diagonal bracing.

[*] Corresponding author: Jishasab13@gmail.com

Keywords. Elevated water tanks, Earthquakes in India, R.C.C. elevated water tanks, Damage or collapse, Incorrect staging geometry.

1 Introduction

Humans require water to survive on a daily basis. The design of a water tank at a particular location determines how well water is distributed. A big water storage tank known as an elevated water tank is designed to keep water supplies at a specific height in order to induce the water distribution system [1]. Many inventions and creative concepts have led to the development of different methods for storing water and other liquid components. There are several ways to store liquid, including elevated, underground, and ground-supported methods [2]. Liquid storage tanks are widely used by enterprises and municipalities to store flammable liquids such as water and chemicals. For this reason, water tanks are essential to both public service and industrial structure [3-4]. Water tanks are essential components of a lifeline. They are crucial element of many industrial sites' water storage systems, municipal water supplies, and firefighting apparatuses [5]. There are three main types of water tanks: elevated, underground, and resting on the ground. The earth immediately supports the stationary tanks that are sitting on the ground, such as settling tanks, aeration tanks, and clear water reservoirs [6-7]. The walls of these tanks are under pressure, and the bases are susceptible to water weight and ground pressure [8]. The tops of the tanks might be covered. From a design perspective, the tanks can be categorised based on their shape: round, spherical, conical bottom, Intze type, rectangular, and suspended bottom tanks [9]. When modest capacity tanks are needed, rectangular tanks are offered [10]. Due to the high expense of the formwork, circular tanks are not cost-effective for smaller capacities. From an economic standpoint, the rectangular tanks should ideally have a square layout. It is preferable if the longer side is no more than twice as long as the smaller side [10]. Vibrations from earthquakes provide a special danger of damage to the liquid storage tanks [11]. Many above water tanks sustained damage in the last earthquake. A small number of them were on-frame staging, while the majority were shaft staging [12]. An elevated water tank failing during an earthquake is mostly caused by the massive water mass at the top of a thin staging. Strategically significant and indispensable construction are elevated water tanks [13]. When these structures sustain damage during an earthquake, the availability of safe drinking water may be compromised, fighting big fires may become more challenging, and substantial financial losses may ensue. Given that elevated tanks are frequently used in seismically active regions, a detailed analysis of their seismic behaviour is required [14]. Due to the ignorance of the supporting system, some of the water tanks broke or sustained serious damage. Therefore, while using alternative supporting systems that are both more robustly engineered, it is vital to consider the seismic safety of lifeline structures [15]. A high degree of accuracy should be used in the design of new tanks and the safety assessment of existing tanks because the failure of such structures, especially during an earthquake, may be catastrophic. The hydrodynamic pressures that tanks experience during seismic activity are a significant factor in tank design. Elevated water tanks are susceptible to significant horizontal forces and overturning during an earthquake [16]. Because of its basic design, which consists of a massive mass concentrated at the top with a relatively slender supporting structure, these tanks are highly susceptible to damage during earthquakes [17]. In regions with strong seismic activity, the design of these structures is mostly governed by earthquake forces when the tank is operating at maximum capacity [18]. Making ensuring that necessities like the water supply are not harmed during earthquakes is crucial. Tanks shall not topple over wholesale in the worst situation [19]. The main aim of this study is to try to understand the behavior of different bracing systems for the purpose of strengthening of the conventional staging and make it more effective during earthquake conditions. Equivalent static analysis carried out to the elevated circular water tank staging in the seismic zone for different types of bracing systems [20].

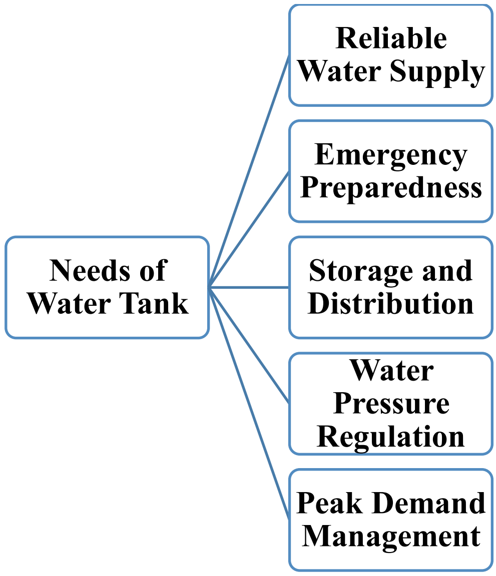

Fig 1: Needs of water supply

2 Methodology

The purpose of the introduced study is to carry out detailed research on the behavior exhibited by increased circular water tanks under seismic activity. This study presents research for the improvement of the knowledge base regarding the dynamic behavior of elevated circular water tanks by experimental study of the structural behavior of increased circular water tanks in seismic conditions. Braced circular water tanks of three different bracing types—cross bracing, diagonal bracing, and alternate diagonal bracing—are taken up for research. The project gives the comparative study to find out reasonable behavior for recognition of general design and height. The heights and capacities of the water tanks are well-designed with fixed support using Staad Pro. The height of the tank is 5 meters, whereas the staging height is 12 meters. Three kinds of bracing have been incorporated into the model: cross bracing, diagonal bracing, and alternative diagonal bracing. The structural materials used here are Fe500-grade steel and M30-grade concrete. This paper presents very complex reactions in circular elevated water tanks, caused by unique bracing arrangements, and it helps in understanding the dynamic behavior of such tanks, with some of the extremely important information for seismic-resistant design considerations.
Table shows that a total of 8 columns and 20 bays along the periphery are taken into account during modelling. The structure also has four bays along the length of it. The tank's geometric measurements are as follows: 4.5 metres for the radius, 5 metres for height, and 12 metres for the staging height. We have carefully defined the structural characteristics to meet the given size specifications. This comprehensive method provides an appropriate representation in the model by generating and assigning attributes for beams, columns, and plate thicknesses. The section parameters have been properly defined, with the tank bottom beam measuring 450 x 600 mm, the floor beams measuring 300 x 450 mm, the columns measuring 500 x 500 mm, and certain plate thicknesses taken into account. The thickness of the bottom plate is 250 mm, and the wall and ceiling have 180 mm and 150 mm thicknesses, respectively,

for the three types of bracing trees: cross, diagonal, and alternate diagonal bracing. The Staad-Pro model captures the subtle dimensions and structural features necessary for an in-depth and accurate structural analysis by integrating these specific section qualities

Table 1: The geometry of the braced elevated water tank

Shape of tank	Circular
Size Capacity	3 lack litters
Roof Slab Thickness	150 mm
Thickness of wall	180 mm
Thickness of Floor Slab	250 mm
Bottom Beam Size	450mm x 600 mm
Floor Beam Size	300mm x 450 mm
Size of Braces	300mm x 450 mm
Column Size	500mm x500mm
Height of Tank	5 m
Tank Diameter	9m
Staging Height	12 m
Type of Staging	Frame Staging
Free Board	0.3 m
Concrete Grade	M30
Steel Grade	Fe 500
Bearing capacity of soil	230KN/m2
Soil density	18KN/m3
Water density	10Mg/m3

3 Results and Discussion

Water tanks serve as vital structures for storing liquids used for various purposes essential in our daily lives. They are indispensable for drinking water, firefighting, irrigation, rainwater collection, and storage of chemicals and gases in industrial sectors. The elevated water tank is build-up of structural components such as footings, beams, columns, and slabs. Subjected loads are passed between these components and ultimately to the soil's sub-grade. The elevated water tank exhibits distinct behaviours depending on the type of loading (Dead, Live, and Seismic). The overhead tank analysis is helpful. Indian standards codes recommend different load combinations that support the probability of an occurrence. The results for analysis of a circular elevated water tank with varying bracing configurations, including cross bracing, diagonal bracing, and alternate diagonal bracing, with same height and capacity. The study primarily focused on a comparative evaluation of critical structural parameters, namely maximum axial force, maximum bending moment, The obtained results are presented below, providing a comprehensive overview of the tank's performance under different bracing scenarios. This comparative study offers valuable insights into the nuanced variations in structural behaviour, facilitating a deeper understanding of the implications of each bracing type on the tank's overall stability and resilience.

Table 2 presents the maximum bending moments experienced through specific columns, every diagnosed through a completely unique column number. These are bending moments of the column in kilonewton-meters (kNm) and provide useful information about the structural performance under the action of the applied loads on it. Column 6 is registered with the highest bending moment of 288 kNm, meaning considerable bending stress for such a special column. Column 14 shows a decreased bending moment of 93 kNm, whereas Column

22 registers a bending moment of 29 kNm, and Column 30 has a value of 15 kNm, with the lowest of all. Additionally, this information aids in refining structural fashions and optimizing designs to decorate average structural overall performance and resilience.

Table 2: maximum bending moment of circular elevated water tank with cross bracing for 3 lack litters

S No	Column No.	Max Bending Moment in KNm
1	6	288
2	14	93
3	22	29
4	30	15

Table 3: maximum axial force of circular extended water tank with cross bracing for 3 lack litters

S No.	Column No.	Max Axial Force in KN
1	6	1225
2	14	775
3	22	572
4	30	354

The Table 3 gives insights into the maximum axial forces experienced by specific columns, every identified through the use of a unique column range. These axial forces, measured in kilonewtons (kN), are important indicators of the compression or tension exerted along the longitudinal axis of the columns under applied loads. Column 6 demonstrates the highest recorded axial force of 1225 kN, suggesting significant compression alongside its longitudinal axis. In assessment, Column 14 experiences a lower axial pressure of 775 kN, accompanied by way of Column 22 with 572 kN, and Column 30 with the lowest axial pressure of 354 kN furthermore, this statistic allows the refinement of structural models and optimization of designs to enhance common structural overall performance and resilience.

Table 4: Maximum bending moment of circular elevated water tank with diagonal bracing for 3 lack litters

S No.	Column No.	Max Bending Moment in KNm
1	6	322
2	14	96
3	22	34
4	30	25

The Table 4 offers the maximum bending moments experienced by specific columns, every identified by a unique column number. these bending moments, measured in kilonewton-meters (KNm), indicate the significance of bending stress that every column undergoes under applied loads. Column 6 exhibits the highest recorded bending moment of 322 KNm, indicating significant bending stress along its length. In comparison, Column 14 experiences a lower bending moment of 96 KNm, followed by Column 22 with 34 KNm, and Column 30 with the lowest bending moment of 25 KNm. Moreover, this fact assists in refining structural models and optimizing designs to enhance overall structural performance and resilience.

Table 5: Maximum axial force of circular elevated water tank with diagonal bracing

S No.	Column No.	Max Axial Force in KN
1	6	1420
2	14	1382
3	22	915
4	30	625

The given table 5 shows the maximum axial forces the specific columns—each identified by a highly unique column number—can experience. These axial forces, expressed as kilonewton (kN), indicate the level of compression or tension along each column's longitudinal axis when loads are applied. With an axial force of 1420 kN, Column 6 has the highest recorded value and appears to have undergone severe compression along its length. Considering carefully, Column 14 undergoes an examination with a significant axial force of 1382 kN, whereas Columns 22 and 30 undergo relatively less axial forces of 915 kN and 625 kN, respectively. Engineers can ensure that column are safely constructed and reinforced to bear predicted loads while maintaining safety standards by employing this research of these axial forces.

Table 6: Maximum bending moment of a circular elevated water tank with alternating diagonal bracing with 3 lack litters

S No.	Column No.	Max Bending Moment in KNm
1	6	340
2	14	98
3	22	53
4	30	45

The Table 6 provide highest bending moments that particular columns have encountered are displayed in the table, each column being uniquely designated by a number. These bending moments, which are measured in kilonewton-meters (KNm), are the maximum bending moment that each column encounters when a load is applied. Column 6 exhibits significant longitudinal bending stress, with a maximum bending moment of 340 KNm. As per the assessment, Column 14 exhibits the highest bending moment of 98 KNm, whereas Column 22 and Column 30 have the lowest bending moments of 53 KNm and 45 KNm, respectively. This determine is essential for structural engineers because it offers invaluable knowledge insights about the load-bearing capacity and structural behaviour of columns within a structure.

Table 7: Maximum axial force of a circular elevated water tank with three lack litters and alternating diagonal

S No.	Column No.	Max Axial Force in KN
1	6	2195
2	14	2160
3	22	1035
4	30	720

The Table 7 provides information on the maximum axial forces that particular column, each identified by a distinct column number have to withstand. These axial forces, measured in kilonewtons (kN), constitute the importance of compression or tension along the longitudinal axis of each column under applied loads. Column 6 demonstrates the highest recorded axial force of 2195 kN, indicating significant compression along its period. Following closely, Column 14 experiences a substantial axial force of 2160 kN in comparison, Columns 22 and 30 experience relatively lower axial forces of 1035 kN and 720 kN, respectively.

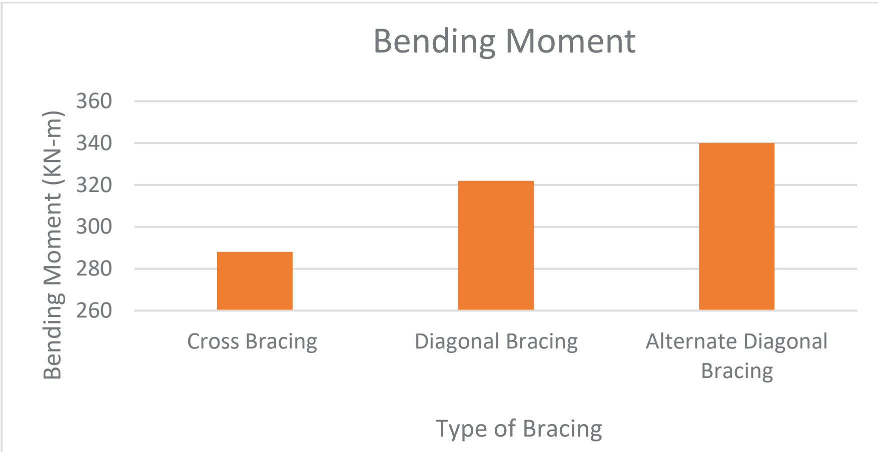

Fig. 2: Comparatively result of bending moment for cross bracing, diagonal bracing and alternate diagonal bracing

The Fig 2 presents a comparative analysis of the maximum bending moments experienced under three different bracing configurations: cross Bracing, Diagonal Bracing, and alternate Diagonal Bracing. Bending moments are crucial indicators of the bending stresses exerted on structural elements, such as columns due to applied loads. Diagonal Bracing results in slightly higher bending moments in comparison to cross Bracing, with the values consistently higher throughout all scenarios. Similarly, alternate Diagonal Bracing induces the highest bending moments among the three configurations, with values constantly exceeding those of cross Bracing and Diagonal Bracing.

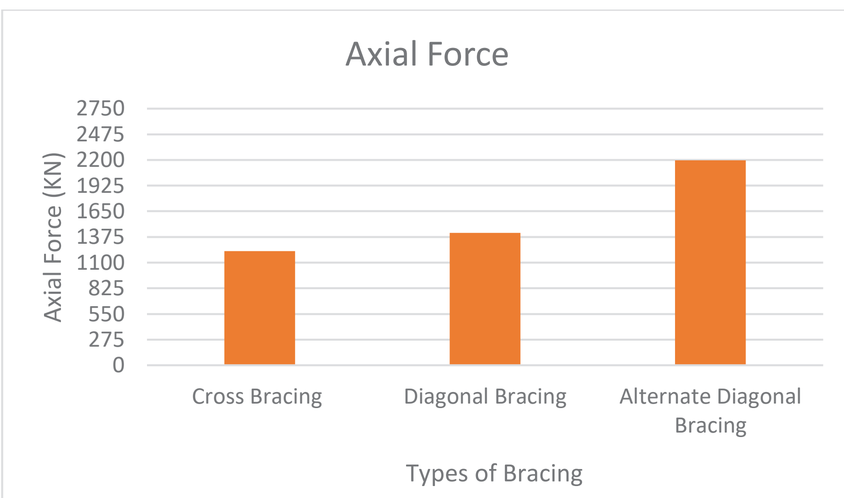

Fig. 3: Comparatively result of axial force for cross bracing, diagonal bracing and alternate diagonal bracing

The Fig 3 provided a comparative analysis of the maximum axial forces experienced under three different bracing configurations: cross Bracing, Diagonal Bracing, and alternate Diagonal Bracing. Axial forces represent the compression or tension exerted along the longitudinal axis of structural members, such as columns or beams, due to applied loads. Diagonal Bracing results in higher axial forces as compared to cross Bracing, with values consistently exceeding those of cross Bracing across all scenarios. Similarly, change Diagonal Bracing induces the highest axial forces among the three configurations, continually yielding values better than the ones of cross Bracing and Diagonal Bracing

4 Conclusion

This study undertakes a comprehensive analysis of the behaviours exhibited by elevated circular water tanks when subjected to seismic conditions. The primary goal of this research is to better understand how various bracing patterns behave in order to reinforce traditional staging and improve performance during earthquakes. An equivalent response study was conducted for the elevated circular water tank staging in zone III, utilising several bracing system types. The results for analysis of a circular elevated water tank with varying bracing configurations, including cross bracing, diagonal bracing, and alternate diagonal bracing, with same height and capacity. The study primarily focused on a comparative evaluation of critical structural parameters, namely maximum axial force, maximum bending moment.

- Analyze behavior of elevated circular water tanks under seismic conditions. Focuses on understanding bracing patterns to enhance conventional staging.
- Conducts equivalent response analysis for staging with different bracing systems. analyze varying bracing configurations (cross, diagonal, alternate diagonal) with same height and capacity.
- The alternate diagonal bracing experiences the highest axial force of 2195 kN, whereas under diagonal Bracing, it's 1420 kN, and under Cross Bracing, it's 1225 KN.
- The alternate diagonal bracing" configuration induces the highest bending moment of 340 KNm, followed by diagonal bracing with 322 KNm and cross bracing with 288 KNm.
- The alternate diagonal bracing" consistently yields the highest bending moments as compared to diagonal bracing and cross bracing.

References

1. Gandhi, Manish N., and Ancy Rajan. "Earthquake Resistant Analysis of Circular Elevated Water Tank with Different Bracings in Staging." IJISET-International Journal of Innovative Science, Engineering & Technology 3, no. 11 (2016): 255-259.
2. MAHENDRA, PRASAD. "Effect Of Defferent Bracing Configuration On The Seismic Performance & Economy Of Intz Water Tanks." (2007).
3. Pathak, Ajay Kumar, and Abhishek Mishra. "Seismic assessment of different vertical bracing systems in staging of elevated liquid retaining tank." Materials Today: Proceedings (2023).
4. Varughese, Shirley Susan, and Vivek Philip. "Effect of Bracing system on Seismic Behavior of Rectangular Elevated RC Water Tank." International Research Journal of Engineering and Technology 4, no. 05 (2017): 3200-3203.
5. Patel, Hardik V., Jasmin A. Gadhiya, and Abhishek Raturi. "Analysis of Elevated Square Water Tank with Different Staging System."

6. Adhikari, Sneha, Imtiyaz A. Parvez, and Kiran Kamath. "Study of Tank with Inclined Braced Staging." International Journal of Innovative Research in Science, Engineering and Technology 5, no. 9 (2016): 66-72.
7. Dutta, Somnath, Aparna Mandal, and Sekhar Chandra Dutta. "Soil–structure interaction in dynamic behaviour of elevated tanks with alternate frame staging configurations." Journal of sound and vibration 277, no. 4-5 (2004): 825-853.
8. Workeluel, Nathnael, Purnachandra Saha, Selemon Matiyas, and Tribikram Mohanty. "A comparative study on analysis and design of RC C elevated water tank using different country codes." Materials Today: Proceedings (2023).
9. Mor Vyankatesh, K., and T. More Varsha. "Comparative study on dynamic analysis of elevated water tank frame staging and concrete shaft supported." IOSR Journal of Mechanical and Civil Engineering(IOSR-JMCE) 14, no. 1 (2017): 38-46.
10. Sandeep, T. D. "A comparative study on elevated water tank due to dynamic loading." international research journal of engineering and technology (irjet) 4, no. 05 (2017): 2000-2004.
11. Dixit, Abhishek. "Comparative Seismic Analysis Between Elevated Circular Water Tanks Using Equivalent Static Method and Response Spectrum Method." In Advances in Geotechnics and Structural Engineering: Select Proceedings of TRACE 2020, pp. 373-384. Singapore: Springer Singapore, 2021.
12. Sharma, Vaibhav, and Abhilash Shukla. "Comparison of Square and Circular Water Tanks." (2016).
13. Khedikar, Amey R., and Abhishek Pandey. "Seismic Analysis and Comparative Study of Elevated Storage Tank by GSDMA Guidelines."
14. Patil, Ankita R., and S. A. Bhalchandra. "Effect of Different Staging Configurations on Seismic Performance of Circular Elevated Water Tank." International Journal of Engineering Research and Applications 4 (2014): 39-43.
15. Rana, Yogesh, and Abbas Jamani. "Comparative Study of Annular Raft Foundation & Solid Circular Raft Foundation for Different Diameter of Water Tank." International Research Journal of Engineering and Technology 5, no. 04 (2018): 3428-3436.
16. Soniwala, Anik N. "Comparative Study on Effect of Different Configuration of Horizontal Bracings on the Performance of Elevated Water Tank." (2020).
17. Mali, Amit K., and Harsh Desai. "Performance of Various Staging Systems for Elevated Water Tank."
18. Singh, Vaibhav, Manik Seth, and Anirban Dhulia. "Analysis and Design of Elevated RCC Water Tank." (2021).
19. Atalkar, Gaurav, and Anand Gharad. "Comparative Analysis Of Elevated Water Storage Structure Using Different Types Of Bracing Patterns In Staging." i-Manager's Journal on Structural Engineering 3, no. 1 (2014): 1.
20. Anjum, Tayyaba, and Mohd Zameeruddin. "Evaluation of Efficacy of the Elevated Water Tank Under the Seismic Loads." International Journal of Civil Engineering 8 (2021): 20-26.