Comparative Study of RCC Rectangular Underground Water Tanks Considering earth quake and without earth quake condition

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Abstract. There are various kinds of water tanks and reservoirs that are used for storing different liquids such as water, petroleum, and chemicals. Residential and commercial use of water tanks is essential in order to meet the needs of those living in these places on a daily basis. During their lifetime, these tanks are subjected to the pressure of the water inside and the pressure of the earth outside. The tank bases are subjected to soil reaction from the bottom and internal water pressure from the inside. In order to protect them from top to bottom, they are always covered from top to bottom. Providing optimum height for easy pumping of water to the overhead tank is the purpose of this rectangular underground tank. Due to the underground nature of the water tank, lateral earth pressure and water pressure also need to be considered during design calculations, so the design must comply with IS code standards. An underground rectangular tank is designed in this project. Our project involves the design and research of an underground water tank capable of holding 3 lakh litters under earthquake conditions. The design in this project comprises of side walls, base slab and roof slab. STAD.PRO is used for the analysis and design of underground water tanks. For this design project limit state method is used. Researchers investigate parameters related to water tanks, including shear force and bending moment, to better understand how they respond to seismic forces, and to aid in more effective design and construction.

Keyword-: Water pressure, Earth pressure, Soil reaction, Tank bases, Covered tanks, Underground tanks.

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1 Introduction

Water tanks are one of the essential infrastructural components that are used for the storage and supply of potable water for drinking, domestic, commercial, industrial, as well as other purposes. Scarcity, erratic supply, and security of water are the factors that make tanks installation in urban, rural, and industrial settlements inevitable [1]. The size of water tanks can vary from small, medium to big and made-up of any material. The underground water tanks are designed to be installed at a position below the ground level and therefore offer a discreet and space-saving option for storing water[2]. They protect the weathering elements, hence are found to be of great use at places where extreme weather conditions exist, or the scenic beauty of the ambiance needs to be maintained [3]. In the case of highly crowded urban metropolitans where the ground at the surface is available in very restricted quantities, the underground water tanks are quite useful indeed. Also, they are used in storing water in making full utilization of space processes in businesses, homes, and industries [4]. Underground water tanks are used to store fluids, such as gas, oil and water. Both internal and external water and earth pressure are applied to these tanks [5]. Tank bases are subjected to internal water pressure and soil reaction from below. These are always completely covered. These tanks should to be specially built for loading, since that produces the least useful results [6]. Underground tank’s function and are designed in the same way as above-ground tanks. Both external soil pressure and internal water pressure can affect the walls of underground tanks. The wall segment is designed to operate under water pressure and subsurface pressure simultaneously and independently [7]. The unpredictable and strong movements of the Earth's crust cause seismic loads, which present a significant obstacle for structural engineers. The fact that they have the ability to exert powerful forces and significantly distort subterranean water tanks highlights how crucial it is to be prepared and knowledgeable [8]. These loads can inflict havoc on structures that are not designed to withstand their impact because of their very characteristics, which are often characterized by their suddenness and quantity [9]. Seismic pressure creates special obstacles for underground water tanks. These underground, hidden facilities are in charge of protecting this important resource: water [10]. But just the force of an earthquake can turn the peaceful surroundings into a conflagration of potential destruction. These tanks have to be able to bear the weight of the water as well as the fury of the elements due to the fact they are protector of an essential resource [11]. It is crucial to make sure they'll be robust and resilient enough to continue to exist a seismic attack like this. Past the bodily international, form disintegrate can have an extended manner-achieving consequences that endanger lifestyles itself, worsen emergency conditions, and disrupt supply lines [12]. For this reason, it is evident that an in-depth study into know underground water tanks behave under seismic loading situation is essential. This calls for a thorough examination of the seismic forces causing these tanks move, shake, and shake in the face of such a powerful opponent [13]. Under addition, the evaluation in their performance under those harsh circumstances acts as a safety beacon, supporting engineers and designers in growing structures that can withstand unanticipated occurrences. The main goal of this study is to ensure that these tanks keep to characteristic as effective defenses during seismic interest, in preference to best comprehending the nuances of seismic behaviour, as compared to simply understanding the subtleties of seismic behaviour [14]. It entails transforming engineering expertise into public mental peace. It involves using knowledge to defend oneself against the force of nature. And it's about reinforcing the concept that safety and functionality are not just ideals—they are the very foundations upon which structures and societies stand. The research and design of an underground water tank with a 3-lakh trash capacity, both with and without earthquake conditions in both full and empty tank condition, are the focus of this project [15]. The design of this project consists of base and roof slabs as well as side walls. Subterranean water tank analysis and design are done with Staad.pro. This design task is approached using the limit state method. Shear force and bending moment are two of the factors included in the study, which is centered on the tanks. It offers crucial information on how earthquakes affect water tanks, information that might improve construction and design techniques [16].

2 Methodology

Underground water tanks are used to store fluids, such as gas, oil and water. Both internal and external water and earth pressures are applied to these tanks. Soil reaction from below and internal water pressure are factors that affect tank bases. These are always well taken care of. These tanks should to be built for loading, since that produces the least useful results. This study is targeted towards presenting the comparative evaluation of rectangular water tank considering with earthquake and without earthquake in zones of iv and soil type -soft to recognize the behaviours of the structure while dead load, live load and seismic load are carried out at the structure. Use of the staad. Pro software completes the modelling and analysis. Rectangular underground water tanks in two distinct states—full and empty—are taken into consideration for study in order to determine the realistic behaviour with and without an earthquake in relation to the overall plan and elevation. The water tank is modelled for soil type -soft and zone IV. Staad Pro is used to provide fixed support for the models that use the Response Spectrum seismic analysis approach. Tank is 6 metres height, with zone IV soil and soft soil types. A 5% modal damping is expected when using I=1 and OMRF. To be secured at the bottom. M30 concrete grade and Fe415 steel are the materials used. The investigation centres around of the tanks, encompassing parameters such as, shear force, bending moment, the research contributes valuable information to the understanding of water tank responses to seismic forces, aiding in improved design and construction practices.

Table 1: Model Specifications of the rectangular underground wate tank

Model Specification	
Component	**Size**
Shape of tank	Rectangular
Capacity of tank	3lack
Tank length	10m
Width of tank	6m
Height of tank	6m
No of bays along length	1
No of bays along width	1
No of bays along height	1
Plate Thickness	300mm
Free Board	200mm
Bearing capacity of soil	230KN/m2
Soil density	18KN/m3
Water density	10Mg/m3
Grade of concrete	M30
Grade of steel	415

Table 1 showing that the dimensions of a rectangular water tank with a 3 lack capacity are described in the model specification that is supplied. The tank has a single bay along each of its 10 metres of length, 6 meters of width, and 6 meters of height. It is constructed on soil that has a bearing capacity of 230 kilonewtons per square metre and consists of plates with a thickness of 300 millimetres and a freeboard of 200 millimetres. Water has a density of 10, whereas soil has 18. The concrete used to make the tank is M30 grade, and it is reinforced with grade 415 steel. These standards guarantee the structural integrity and functionality of the tank by defining its size, composition, and foundational features.

3 Result and Discussion

Underground water tanks are designed to be buried beneath the ground's surface, offering a discrete and space-efficient solution for storing water. These tanks provide protection from weather elements, making them ideal for regions prone to extreme weather conditions or for areas where preserving the aesthetics of the surroundings is important. In highly crowded urban centres with limited surface area, underground water tanks are useful. They are also frequently used to store water while making the best use of available space in businesses, homes, and industrial facilities. In study to understand the behaviour of the structure when dead load, live load, and seismic load are applied to it, this study compares the evaluation of a rectangular water tank in zones IV and soft soil under earthquake and without earthquake. Applying the staad. Professional software completes the analysis and modelling. Undertakings: Rectangular underground water tanks in two different stages of fulling and emptying are studied to ascertain the realistic behaviour in the event of an earthquake with respect to the overall layout and elevation. Zone IV soil type and soft soil type are modelled for the water tank.

Table 2: Results of shear force in x y and z direction without earthquake

Condition	Rectangular Water Tank		
	FX KN	FY KN	FZ KN
Empty	130	872	65
Full	224	872	91

The Table 2 data provided outlines the forces performing on a rectangular water tank under different conditions: empty and full in without earthquake condition. In the empty condition, the forces exerted at the tank are as follows: an FX force of 130 kilonewtons (KN), an FY force of 872 KN, and an FZ force of 65 KN. Conversely, whilst the tank is full, these forces change. The FX force increases to 224 KN, indicating a greater force within the X direction likely due to the added weight of the water. However, the FY force remains constant at 872 KN, suggesting that the water's weight does not affect this direction. Similarly, the FZ force will increase to 91 KN, compared to the 65 KN when the tank is empty, demonstrating the additional load within the Z direction caused by the water. These force measurements are critical for engineering and structural evaluation, informing the layout of support systems able to withstanding the forces exerted by means of the water within the tank under various conditions.

Table 3: Results of maximum bending in x y and z direction without earthquake

Condition	Rectangular Water Tank	
	MX KN	MZ KN
Empty	298	328
Full	260	304

The Table 3 provided data outlines the moments exerted on a rectangular water tank under different conditions: empty and full in without earthquake condition. In the empty condition, the moments performing on the tank are specified as follows: an MX moment of 291 kilonewton-meters (KN-m), an MZ moment of 320 KN-m. Conversely, while the tank is full, these moments revel in slight changes. The MX moment decreases to 287 KN-m, indicating a slightly decreased rotational force around the X-axis, probable because of modifications in weight distribution as a result of the added water. Similarly, the Z-axis. Extensively, the moment decreases to 304 KN-m, suggesting that the vertical rotational force remains changed the tank's water level. These moment measurements are crucial for structural engineers, informing them about the rotational forces exerted at the tank and assisting within the design of help systems capable of withstanding such forces underneath specific tank conditions.

Table 4: Results of maximum shear force in x y and z direction with earthquake

Condition	**Rectangular Water Tank**		
	FX KN	FY KN	FZ KN
Empty	145	1225	118
Full	245	1225	162

The Table 4 provided data outlines the forces acting on a rectangular water tank in both empty and full situations with earth quake condition. In the empty state, the forces exerted at the tank are specified as follows: an FX force of 145 kilonewtons (KN), an FY force of 1225 KN, and an FZ force of 118 KN. Upon filling the tank, these force values undergo changes. The FX force increases to 245 KN, suggesting a greater force performing along the X-axis because of the introduced weight of water. Conversely, the FY force stays constant at 1225 KN, indicating that the vertical force remains unaffected by the water level. Notably, the FZ force also increases to 162 KN, highlighting the extra downward force attributed to the increased water weight.

The Table 5 provided data outlines the moments exerted on a rectangular water tank in both empty and full in earthquake condition. When the tank is empty, the moments are as follows: an MX moment of 576 kilonewton-meters (KN-m), and an MZ moment of 685 KN-m. Upon filling the tank, these moments experience changes. The MX moment decreases to 536 KN-m, indicating a reduction in the rotational force across the X-axis, possibly due to alterations in weight distribution caused by the added water. Similarly, additionally, the MZ moment decreases barely to 662 KN-m. Although the change isn't as significant, it still shows a lower within the rotational force around the Z-axis.

Table 5: Results of maximum bending in x y and z direction with earthquake

Condition	**Rectangular Water Tank**	
	MX in KN	MZ in KN
Empty	576	685
Full	536	662

The Fig 1 provided outlines the forces performing on a rectangular water tank under different conditions: empty and full in without earthquake condition. In the empty condition, the forces exerted at the tank. The maximum value of shear force in FY direction as compared to FX and FZ in both empty and full tank condition. The maximum value of shear force in full tank when tank is empty, shear force is reduced. These force measurements are critical for engineering and structural evaluation, informing the layout of support systems able to withstanding the forces exerted by means of the water within the tank under various conditions.

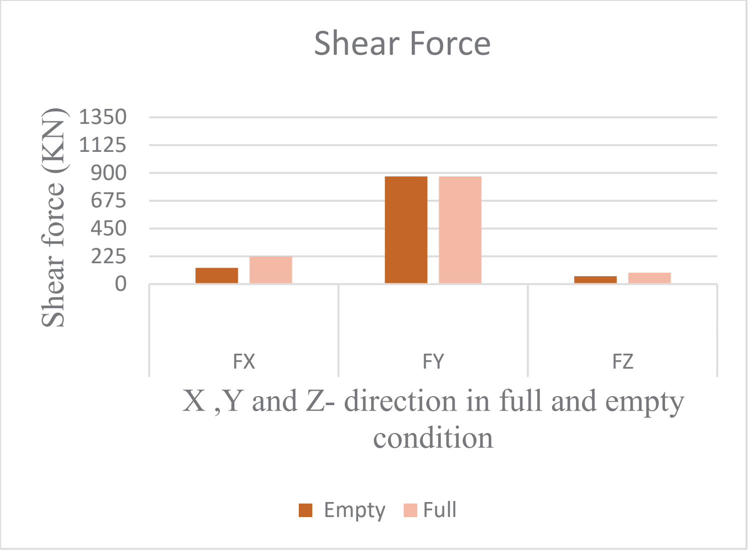

Fig. 1: Comparatively analysis of shear force in without earthquake for empty and full condition

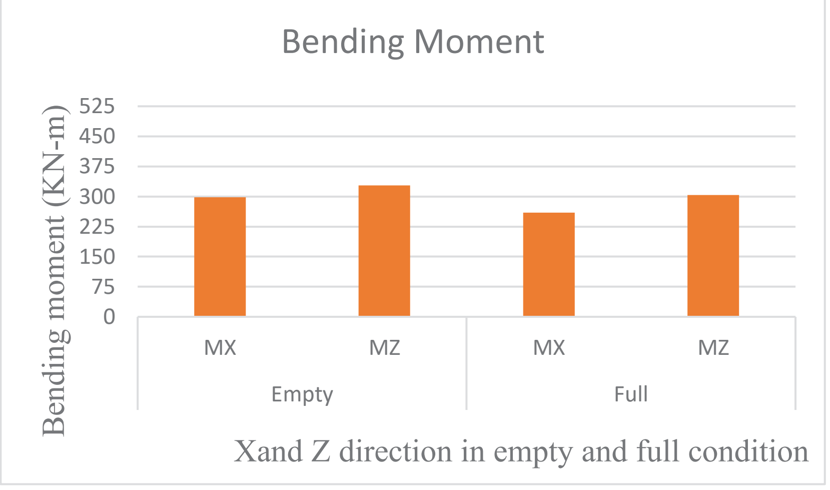

Fig 2: Comparatively analysis of bending moment in without earthquake for empty and full condition

The Fig 2 provided outlines the forces performing on a rectangular water tank under different conditions: empty and full in without earthquake condition. In the empty condition, the forces exerted at the tank. The maximum value of bending moment in MZ direction as compared to MX- direction in both empty and full tank condition. The maximum value of bending moment in empty tank when tank is full, moment is decreased. These moment measurements are crucial for structural engineers, informing them about the rotational forces exerted at the tank and assisting within the design of help systems capable of withstanding such forces underneath specific tank conditions.

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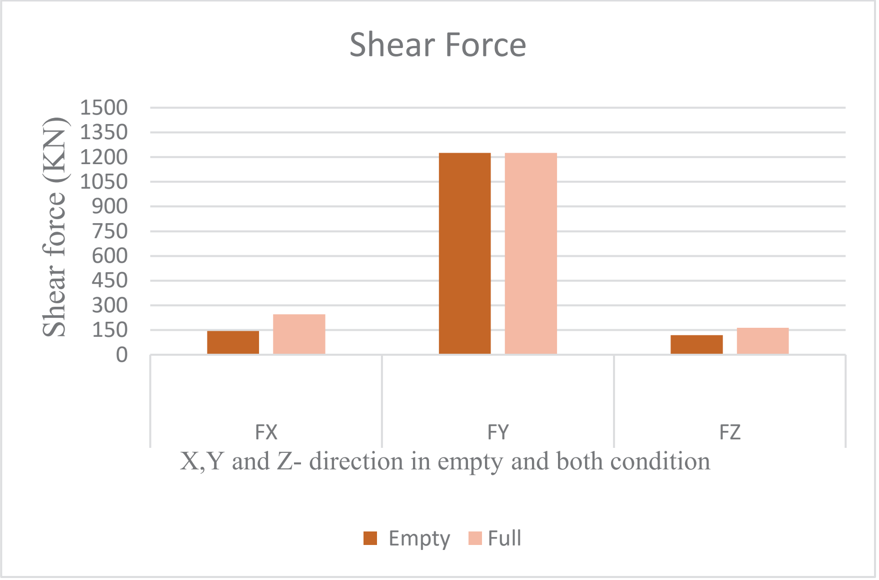

Fig 3: Comparatively analysis of shear force in with earthquake for empty and full condition

The Fig 3 provided outlines the forces performing on a rectangular water tank under different conditions: empty and full in with earthquake condition. In the empty condition, the forces exerted at the tank. The maximum value of shear force in FY direction as compared to FX and FZ in both empty and full tank condition. The maximum value of shear force in full tank when tank is empty, shear force is reduced. These force measurements are critical for engineering and structural evaluation, informing the layout of support systems able to withstanding the forces exerted by means of the water within the tank under various conditions.

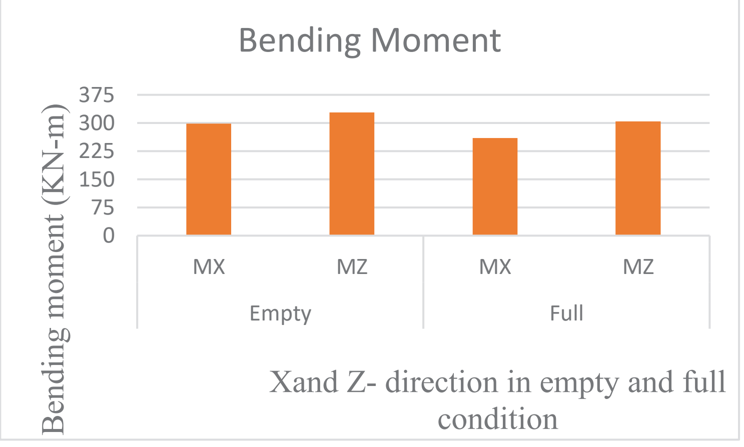

Fig. 4: Comparatively analysis of bending moment in with earthquake for empty and full condition

The Fig 4 provided outlines the forces performing on a rectangular water tank under different conditions: empty and full in with earthquake condition. In the empty condition, the forces exerted at the tank. The maximum value of bending moment in MZ direction as compared to MX- direction in both empty and full tank condition. The maximum value of bending moment in empty tank when tank is full, moment is decreased. These moment measurements are crucial for structural engineers, informing them about the rotational forces exerted at the tank and assisting within the design of help systems capable of withstanding such forces underneath specific tank conditions.

4 Conclusion

Water tanks are an absolute necessity for both residential and commercial uses in order to meet their daily needs. These tanks are subjected to water pressure from inside and earth pressure from outside. Soil reaction from below and internal water pressure are applied to tank bases. In study to understand the behaviour of the structure when dead load, live load, and seismic load are applied to it, this study compares the evaluation of a rectangular water tank in zones IV and soft soil under earthquake and without earthquake. Applying the staad. Professional software completes the analysis and modelling. Undertakings: Rectangular underground water tanks in two different stages of fulling and emptying are studied to ascertain the realistic behaviour in the event of an earthquake with respect to the overall layout and elevation. Zone IV soil type and soft soil type are modelled for the water tank.

- Tank moment and shear force measurements: Empty and Full
- In without earthquake condition, Empty tank: FX force of 130 KN, FY force of 872 KN, and FZ force of 65 KN. When tank is full: FX force increases to 224 KN. FY force remains constant at 872 KN, FZ force increases to 91 KN, indicating additional load in the Z direction.
- In without earthquake condition Empty tank: MX moment of 291 KN-m, MZ moment of 320 KN-m. In Full tank: MX moment decreases to 287 KN-m, indicating decreased rotational force around X-axis due to water addition. Z-axis: MX moment decreases to 304 KN-m, indicating vertical rotational force remains, altering tank's water level.
- In with earthquake condition, Empty state: FX force of 145 KN, FY force of 1225 KN, FZ force of 118 KN. Filling state: FX force increases to 245 KN due to water weight. FY force remains constant at 1225 KN, indicating vertical force remains unaffected by water level. FZ force increases to 162 KN.
- In with earthquake condition Empty tank: MX moment of 576 KN-m, MZ moment of 685 KN-m. Filling tank: MX moment decreases to 536 KN-m, possibly due to water-induced weight distribution changes. MZ moment decreases to 662 KN-m, indicating a lower rotational force around the Z-axis.

References

1. Gadekar, Deepshikha, and Rakesh Patel. "Design and Analysis of Under Ground Water Tank Considering Different Fill Conditions Using STAAD. PRO: A Review." 6 (2022): 11-18.
2. Bhende, Amruta Arvind, and Prajakta B. Jamale. "Comparative Analysis of Different Shapes of Underground Water Tank." International Journal of Modern Developments in Engineering and Science 1,5 (2022): 19-21.
3. Chang, Chun, Zhiyong Wu, Helena Navarro, Chuan Li, Guanghui Leng, Xiaoxia Li, Ming Yang, Zhifeng Wang, and Yulong Ding. "Comparative study of the transient natural convection in an underground water pit thermal storage." Applied energy 208 (2017): 1162-1173.
4. Lotfy, Ayman M., Ashraf IG Elhetawy, Mahmoud M. Habiba, and Mohamed M. Abdel-Rahim. "A comparative study on the effects of seawater and underground saltwater on water quality, growth, feed utilization, fish biomass, digestive system development, and blood health in gilthead seabream, Sparus aurata." (2021): 1609-1621.

5. Gocke, Jessica. "The collateral damage of environmental federalism: A comparative study of underground storage tank policy in the United States." PhD diss., University of La Verne, 2012.
6. Bociort, Dalia, C. A. T. A. L. I. N. Gherasimescu, R. A. Z. V. A. N. Berariu, Romen Butnaru, Mihai Branzila, and Ion Sandu. "Comparative studies on making the underground raw water drinkable, by coagulation-flocculation and adsorption on granular ferric hydroxide processes." Revista de Chimie 63, 12 (2012): 1243-1248.
7. Jindal, Bharat Bhushan, Ajay Goyal, and Devinder Sharma. "Comparative Study Of Design Of Rectangular Water Tanks With Reference To Is 3370."
8. Johnston, Moira. "A critical and comparative analysis of the under regulation of underground storage tanks in South Africa and the attendant consequences for environmental resources." (2014).
9. Chang, Ni-Bin, Marty Wanielista, Ammarin Daranpob, Zhemin Xuan, and Fahim Hossain. "New performance-based passive septic tank underground drainfield for nutrient and pathogen removal using sorption media." Environmental Engineering Science 27, 6 (2010): 469-482.
10. Lee, Ho Yeol, Gyu Tae Seo, and Taek Soon Lee. "Comparative Analysis of the Storm Sewer Expansion Methodology and Underground Rainwater Storage Tanks for Urban Flood Control." Journal of Korean Society on Water Environment 29, 6 (2013): 754-761.
11. Wang, Huajun, and Chengying Qi. "Performance study of underground thermal storage in a solar-ground coupled heat pump system for residential buildings." Energy and Buildings 40, 7 (2008): 1278-1286.
12. PATEL, CHIRAG N., and Mehul S. Kishori. "Analytical and Software Based Comparative Analysis of on Ground Circular Water Tank." International Journal of Civil Engineering (IJCE), 5 (3) (2016).
13. Singh, Himmat, Sanjeev Kumar Gupta, Kumar Vikram, Rekha Saxena, and Amit Sharma. "The impact of mosquito proof lids of underground tanks "tanka" on the breeding of Anopheles stephensi in a village in western Rajasthan, India." Malaria journal 20 (2021): 1-10.
14. Rangrej, Junaid, and Hitesh Kodwani. "A Review of Analysis of Underground Water Tanks Considering Different Conditions." International Journal of Innovative Research in Technology and Science 12, 2 (2024): 235-239.
15. Tateishi, Akira. "A study on seismic analysis methods in the cross section of underground structures using static finite element method." Structural Engineering/Earthquake Engineering 22, 1 (2005): 41s-54s.
16. Andreolli, Marco, Nicola Albertarelli, Silvia Lampis, Pierlorenzo Brignoli, Nazaninalsadat Seyed Khoei, and Giovanni Vallini. "Bioremediation of diesel contamination at an underground storage tank site: a spatial analysis of the microbial community." World Journal of Microbiology and Biotechnology 32 (2016): 1-12.