e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

EXPLORING THE VARIATIONS IN CHARACTERISTICS BETWEEN CIRCULAR AND RECTANGULAR UNDERGROUND WATER TANKS THROUGH A PARAMETRIC STUDY

Akash Upadhyay*1, Prof. Harsh Gupta*2

*1Scholar, Civil Engineering Department, JNCT Rewa M.P. 486001 India.

*2Professor & Head Of Civil Engineering Department, JNCT Rewa M.P. 486001 India.

ABSTRACT

A water tank serves as a reservoir for supplying drinking water to households, cooling for industrial processes, and irrigation in specific regions for agricultural purposes. These tanks are categorized based on their shapes and structural placement. This research focuses on underground water tanks of both rectangular and circular shapes, subjecting them to varying loads and soil conditions. The study includes assessments of different types of stresses such as shear force, bending moment, and axial load. The objective is to evaluate how tanks with distinct shapes but identical heights and different capacities perform in these conditions. The primary objectives are to analyze the shear force, bending moment, and axial force distribution in both tank shapes under different loading conditions and capacities. The study concludes that rectangular tanks exhibit higher shear force, and axial force compared to circular tanks, and these forces are influenced by both tank shape and capacity. The findings provide valuable insights into the underground water tanks with varying geometric and loading conditions.

I. INTRODUCTION

In an era marked by rapid urbanization and a burgeoning global population, the effective management of water resources has become a paramount concern. Amidst this backdrop, the imperative of comprehending the complexities inherent in underground water tanks looms large. These tanks serve as linchpins in water supply and distribution systems, impacting the daily lives of communities, industries, and institutions. As these structures operate below the earth's surface, their behavior and response to various factors assume a critical role in ensuring their reliability and longevity [1]. This research embarks on an in-depth exploration, delving into the multifaceted realm of underground water tanks. By systematically manipulating a range of parameters encompassing tank geometry, physical dimensions, material characteristics, soil properties, water levels, and seismic forces, this study aims to uncover a wealth of insights. These insights extend to the intricate interplay between these parameters and their collective influence on the structural behavior of both circular and rectangular underground water tanks. The methodology employed is equally robust, entailing the synergistic utilization of analytical principles and computational simulations. By subjecting the tanks to diverse scenarios, the research endeavors to prognosticate their responses, generating invaluable data that can be harnessed to refine and optimize design strategies. In essence, this study offers engineers and researchers a platform for achieving a heightened comprehension of the tanks' stability, structural resilience, and operational efficacy. This understanding, in turn, not only bolsters the foundations of water storage solutions but also paves the way for the creation of systems that are safer, more adaptive, and inherently prepared to navigate the challenges posed by urbanization and environmental dynamics.

1.1 Significance of Water Storage Structures in Urban and Rural Areas

Water storage structures hold profound significance in both urban and rural areas, serving as critical components of water management systems that directly impact public health, economic development, and overall quality of life. Their multifaceted roles and contributions are essential for ensuring reliable access to clean and safe water, addressing various societal needs and challenges:

Water Security and Accessibility

In urban areas, water storage structures, such as elevated tanks and reservoirs, play a pivotal role in ensuring a consistent and uninterrupted water supply to densely populated communities. These structures serve as storage reservoirs that store treated water from water treatment plants, making it available for distribution during periods of high demand, emergencies, or maintenance activities. In rural areas, water storage structures like wells, ponds, and rainwater harvesting systems enhance water accessibility for domestic, agricultural, and livestock needs.

Emergency Response and Resilience

Water storage structures provide a buffer during emergencies, natural disasters, or unforeseen disruptions in the water supply system. In urban areas, large water storage tanks facilitate firefighting efforts, enabling authorities to access sufficient water for extinguishing fires and safeguarding lives and property. In rural areas, water storage structures can be critical for disaster relief operations, offering a readily available water source during droughts, floods, or other calamities.

Agricultural Sustainability

Water storage structures are indispensable for supporting agricultural activities, which form the backbone of rural economies. In both urban and rural settings, these structures enable efficient irrigation, helping farmers cultivate crops even during dry spells. They also contribute to the storage of rainwater for agricultural use, reducing reliance on groundwater and promoting sustainable water management practices.

Health and Sanitation

Adequate water storage structures are fundamental for promoting hygiene, sanitation, and public health. In urban areas, they ensure a steady supply of water for sanitation facilities, thereby reducing the spread of waterborne diseases. In rural regions, these structures offer access to safe drinking water, minimizing health risks associated with contaminated water sources.

1.2 Seismic Resilience and Its Importance in Water Tank Design

Seismic resilience is a critical and fundamental aspect of water tank design, representing the capacity of these structures to withstand and recover from the dynamic and destructive forces unleashed by earthquakes. The importance of seismic resilience in water tank design cannot be overstated, as it directly influences the safety, functionality, and sustainability of these crucial infrastructure components.

1.3 Overview of Circular and Rectangular Underground Water Tanks

The design and construction of underground water tanks are pivotal components of efficient water management systems, serving urban and rural areas alike. These tanks play a crucial role in storing and distributing water for various purposes, ensuring a reliable and consistent water supply for both normal and emergency conditions. Circular and rectangular underground water tanks represent two prevalent shapes, each with its own set of advantages and considerations [4].

Underground Circular Water Tanks

Circular underground water tanks possess several distinctive structural advantages that make them a preferred choice in water storage system design. The circular shape inherently offers inherent efficiency by evenly distributing forces across its surface, which contributes to enhanced structural stability and integrity. This even stress distribution is a critical factor in ensuring that the tank can withstand a variety of external loads, including water pressure, soil pressure, and potential seismic forces. Circular tanks demonstrate exceptional resilience against external pressures, such as soil pressures exerted by the backfilling material around the tank. The curvature of the circular walls allows for a more uniform distribution of these pressures, minimizing the likelihood of localized stress concentrations that could lead to structural weaknesses or leaks. Moreover, circular tanks are well-suited to withstand seismic forces.

Fig. 1.1 Underground Circular Water Tanks

1.4 Objectives:

- To study the behavior of underground water tank for different parameter.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

- Comprehensive study of rectangular and circular underground water tank
- To study the shear force, axial force, bending moment

II. LITERATURE SURVEY

Chopade and Modani (2019) [1], attention was drawn to the recent revisions in the Indian standard IS 3370, which outlines the code of practice for concrete structures intended for liquid storage. The earlier version of the code, IS 3370:1965, exclusively adopted the working stress method (WSM) for the design of water storage tanks. In contrast, the updated IS 3370:2009 incorporates both the working stress method and the limit state method (LSM). The research paper revolves around a comparative analysis of the design provisions specified in IS 3370:1965 and the revised IS 3370:2009. Notably, the limit state method in IS 3370:2009 focuses on two crucial aspects: confining stress levels within steel elements and controlling the width of cracks. This exploration provides insights into the evolving methodologies and considerations shaping the design practices for water storage structures, showcasing how industry standards have evolved to encompass more comprehensive and contemporary approaches.

(Mondal & Guha, n.d.) [2] In this paper, a comprehensive comparative study is presented, focusing on Reinforced Concrete (R.C.C.) water tanks that are either underground or rest on the ground, and come in circular and rectangular shapes. The investigation specifically targets tanks with a capacity of 500,000 liters or 130,000 US gallons. The study encompasses the entire design and estimation process for these diverse tank configurations, both underground and above-ground. The paper highlights the common challenge of selecting the most appropriate construction type, which often leads to confusion due to multiple available choices. The research's primary objective is to elucidate the decision-making process by designing and analyzing large-capacity R.C.C. water tanks of various shapes. For both types of water tanks, a detailed analysis is conducted using STAAD PRO software, with the ultimate goal of drawing conclusive insights into the comparative merits of the two techniques for the specified capacity.

III. METHODOLOGY

General

This studies is targeted towards presenting the parametric study evaluation of rectangular and circular water tank considering same height and different capacity to recognize the behaviour of the structure while dead load and live are carried out at the structure. The modelling and analysis are completed using staad. pro software program.

Structure

The two different shape of rectangular and circular underground water tank and two different condition full and Empty and the parametric evaluation is considered for analysis to know the realistic behaviour with the general plan and elevation. Water tank is modelled for same height and different capacity for circular and rectangular underground water tank with fixed support using Staad Pro. The height of all tank is 4m and. Modal. Material concrete grade is M30 and while steel Fe415 is used.

3.1 Geometrical Specifications for Rectangular Water Tank for240000 liters Capacity

Table 3.1 Geometrical Specifications of the Structure

Geometrical Specification	
Component	Size
Shape of tank	Rectangular
Capacity of tank	240000 litre
Length of tank	10m
Width of tank	6m
Height of tank	4m
No of bays along length	1

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

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

Parameter of Rectangular Tank

Table 3.2 Parameter of Tank

Parameter of tank				
Shape of tank	,ength inm	Width in m	Height in m	Capacity in litre
Rectangular	10	6	4	240000litre
	8	4	4	128000litre

3.2 Steps of the Modelling and Analysis for Rectangular Water Tank

STEP 1 Research paper from different authors is summarized in this section who have focused towards Analyzing the water tank structure considering seismic loads with zones IV and soft soil.

STEP 2 Staad Pro provides the option of modelling the structure with an easy option of Quick Template where the bays can be defined in X, Y and Z direction. Here in this case, 1 bays in considered in along length and 1 bays in considered in along width and 1 bays along height. structure is considered with length of tank is 10m , height of the tank is 4m and the width of the tank is 6m .

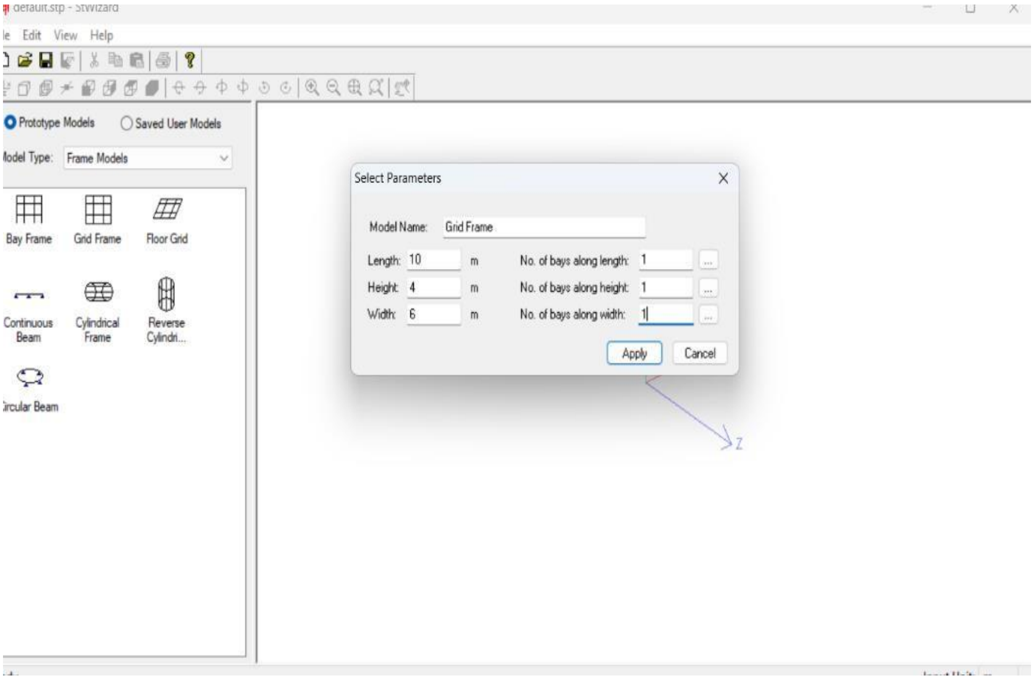

Fig. 3.1 Property Defining of Rectangular Water Tank in Staad Pro

Step-3: Property Definition: Using General-Property command define the property as per size requirement to the respective Structure on staad-Pro. So, thickness of plate have been generated after assigning to selected plate.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

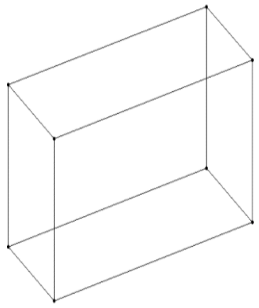

Fig. 3.2 Defining Section Properties for Plate, Size of Plate Thickness 300mm, is Considered in the Study

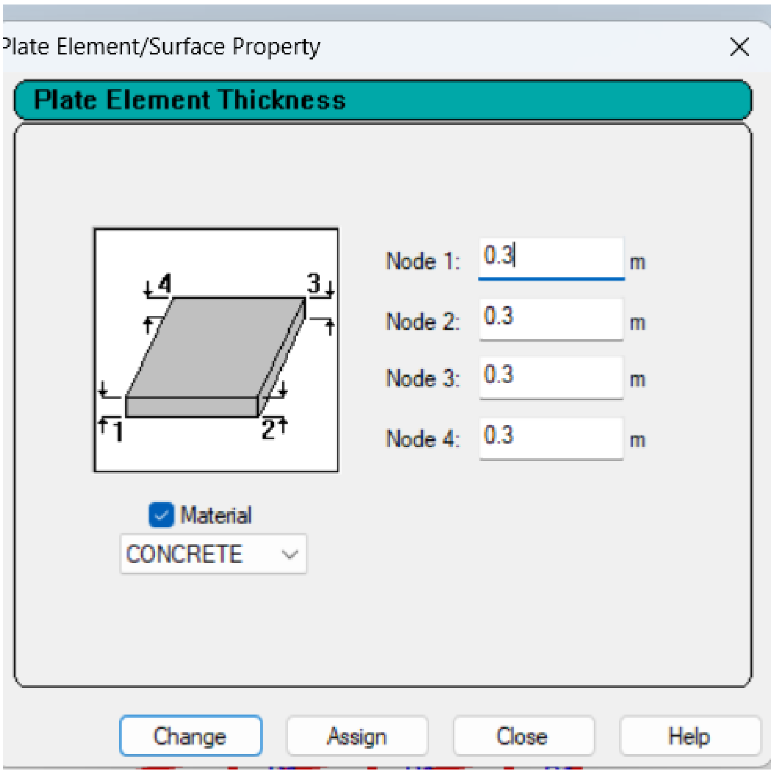

Fig. 3.3 Defining the Properties of Element Thickness

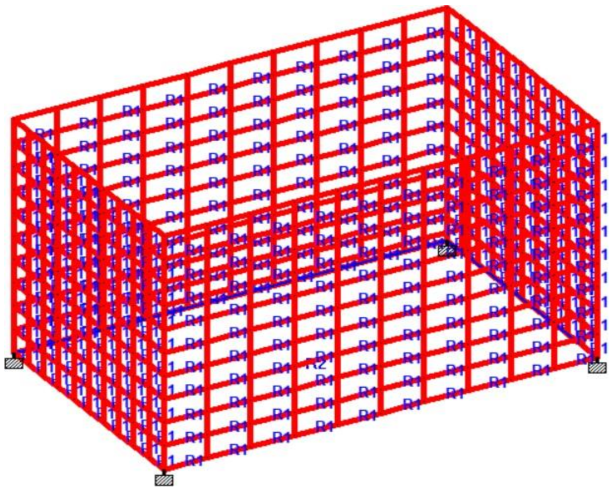

Fig. 3.4 Assigning Properties of Element Thickness

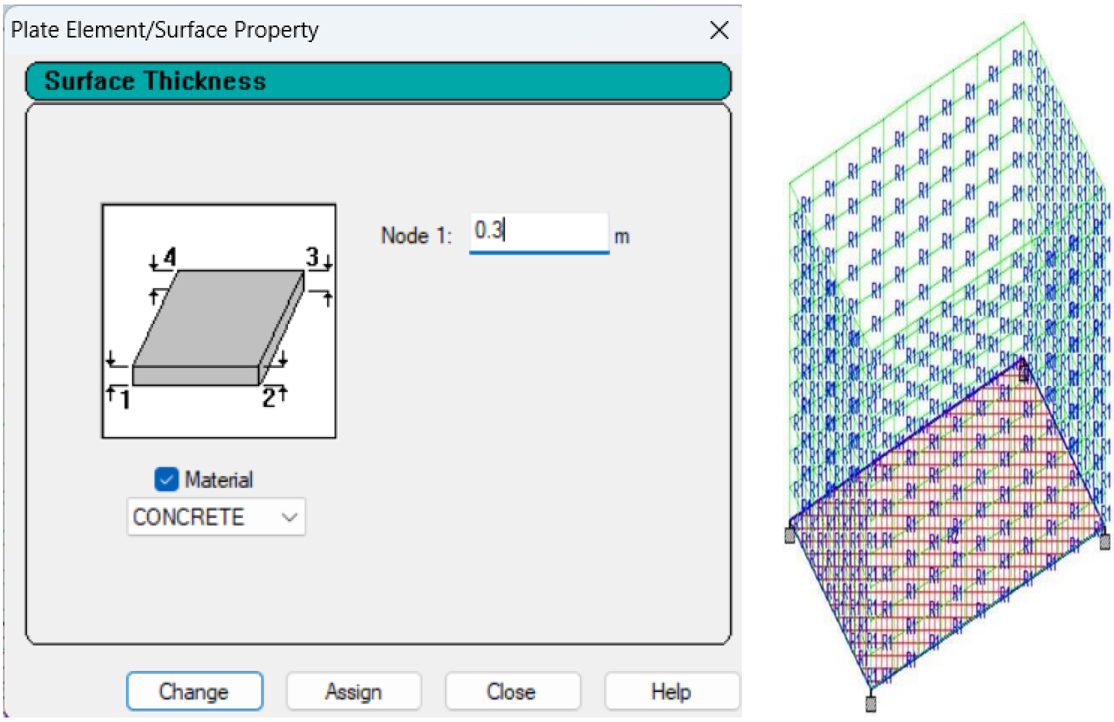

Fig. 3.5 Defining the Properties of Surface Thickness

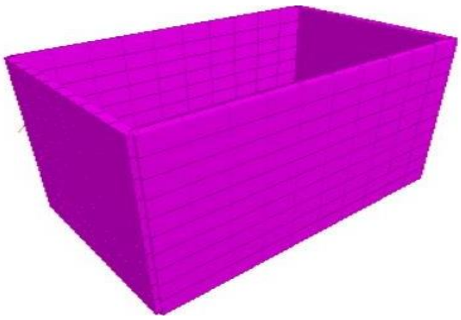

Fig. 3.6 3D Structure of the Tank

STEP 4 Defining Support

Step 4: Assigning supports to the structure

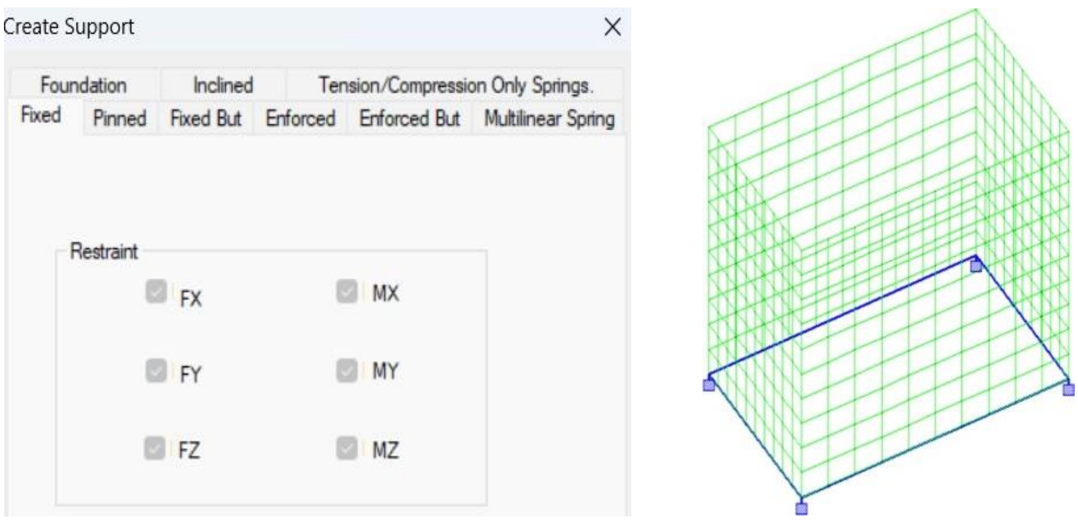

Fig. 3.7 Assigning Supports

STEP 5 Defining Load: Defining Load cases for dead load, live load and seismic analysis.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

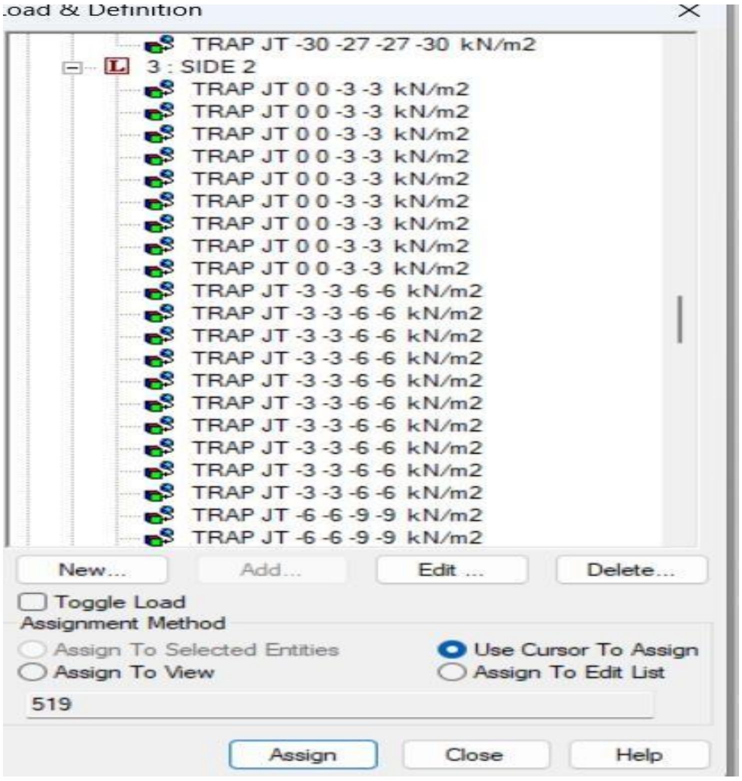

Fig. 3.8 Defining Load

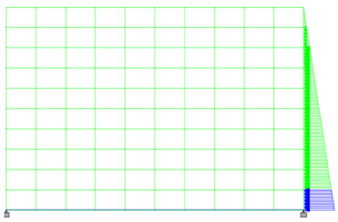

Fig. 3.9 Assigning soil Pressure

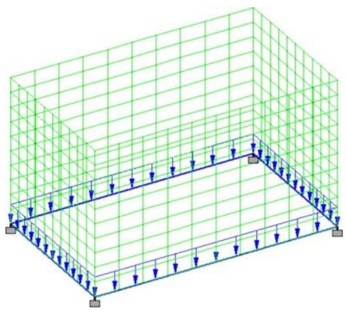

Fig. 3.10 Assigning Surface Pressure

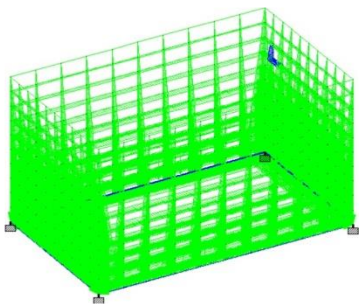

Fig. 3.11 Assigning Load

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

IV. RESULT AND ANALYSIS

General

The parametric study of maximum axial force, maximum shear force Maximum bending moment. The results obtained from analysis are given below and comparative study is carried out which is stated below:

Results for Rectangular Water Tank and Circular Water Tank for 240000 litters Capacity

Results of shear force for Rectangular and circular water Tank

Shear Force

Table 4.1 Maximum Value of Shear Force in X- Direction

SR. NO	Condition of water tank	Types of tank	FX in KN
1	Empty	Rectangular Tank	102.4
		Circular Tank	51.6
2	Full	Rectangular Tank	148.2
		Circular Tank	46.3

Table 4.2 Maximum Value of Shear Force in Z- Direction

SR. NO	Condition of water tank	Types of tank	FZ in KN
1	Empty	Rectangular Tank	35.8
		Circular Tank	51.12
2	Full	Rectangular Tank	53.88
		Circular Tank	46.2

Axial Force

Table 4.3 Maximum Value of Axial Force

SR. NO	Condition of water tank	Types of tank	FY in KN
1	Empty	Rectangular Tank	680
		Circular Tank	235
2		Rectangular Tank	680
	Full	Circular Tank	282

Bending Moment

Results of bending moment for Rectangular and Circular Water Tank

Table 4.4 Maximum value of Bending Moment in X- Direction

SR. NO	Condition of water tank	Types of tank	MX in KNm
1	Empty	Rectangular Tank	287.3
		Circular Tank	478.5
2	Full	Rectangular Tank	276.4
		Circular Tank	527.8

Table 4.5 Maximum Value of Bending Moment in Y- Direction

SR. NO	Condition of water tank	Types of tank	MY in KNm
1	Empty	Rectangular Tank	2.77
		Circular Tank	0.01
2	Full	Rectangular Tank	5.84
		Circular Tank	0.02

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

Table 4.6 Maximum Value of Bending Moment in Z - Direction

SR. NO	Conditions of water tank	Types of tanks	MZ in KNm
1	Empty	Rectangular Tank	350.4
		Circular Tank	478.5
2	Full	Rectangular Tank	341.5
		Circular Tank	527.8

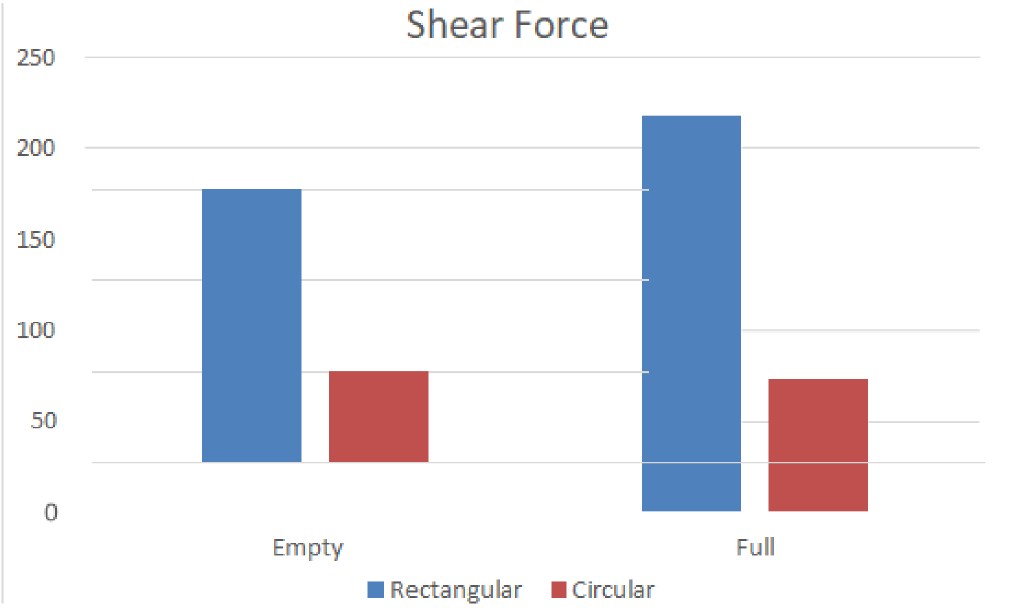

Fig. 4.1 Shear Force for 240000 liters Capacity

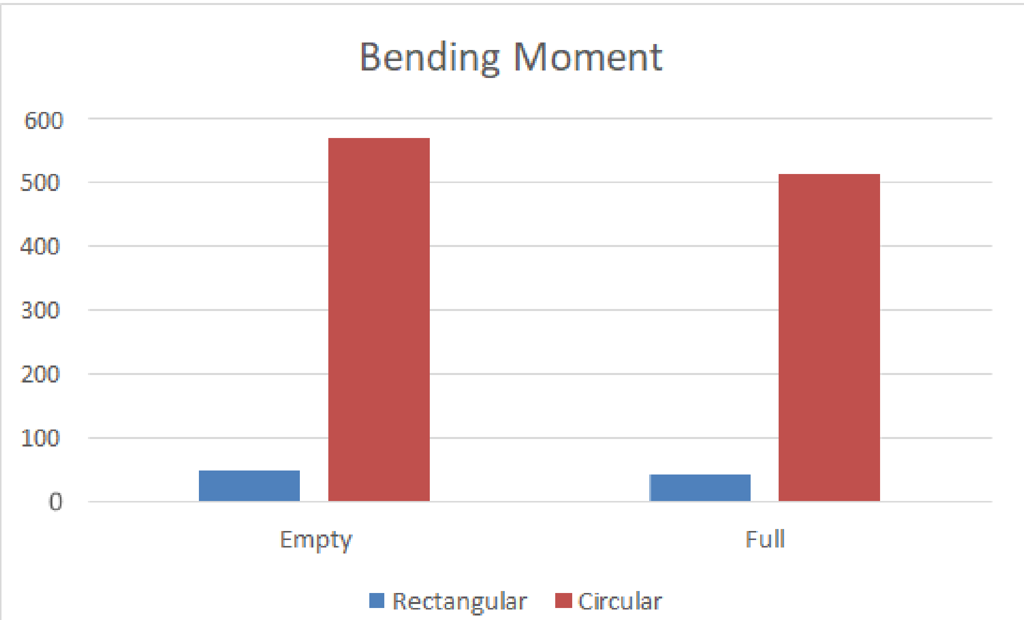

Fig. 4.2 Bending Moment for 240000 liters Capacity

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

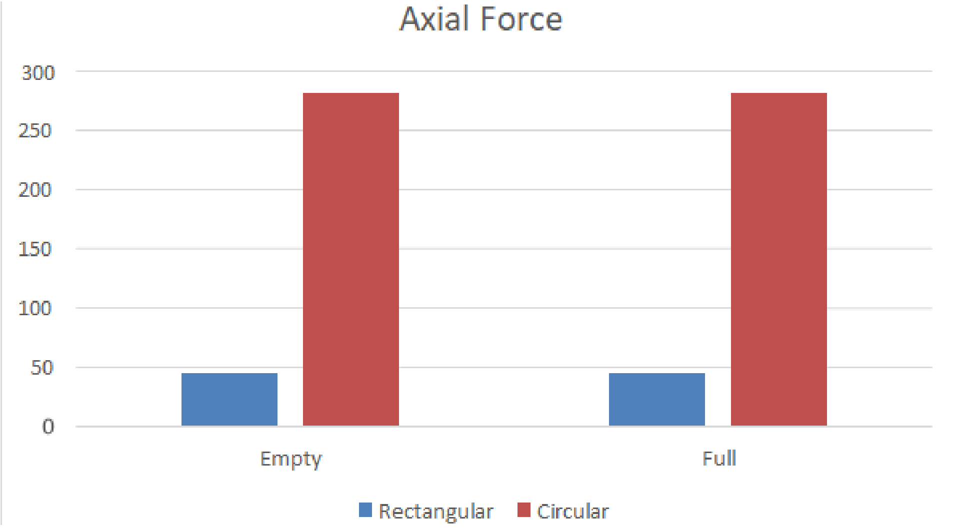

Fig. 4.3 Axial force for 240000 liters Capacity

Results for Rectangular Water Tank and Circular Water Tank for128000 Litres Capacity

Shear Force

Results of shear force for Rectangular and circular water Tank

Table 4.7 Maximum Value of Shear Force in X- Direction

SR. NO	Condition of water tank	Types of tank	FX in KN
1	Empty	Rectangular Tank	60.5
		Circular Tank	36.2
2	Full	Rectangular Tank	84.2
		Circular Tank	48.7

Table 4.8 Maximum Value of Shear Force in Z- Direction

SR. NO	Condition of water tank	Types of tank	FZ in KN
1	Empty	Rectangular Tank	25.4
		Circular Tank	35.7
2	Full	Rectangular Tank	44.2
		Circular Tank	48.2

Axial Force

Results of shear axial force for Rectangular and circular water Tank

Table 4.9 Maximum value of Axial Force

SR. NO	Condition of water tank	Types of tanks	Axial Force in KN
1	Empty	Rectangular Tank	395.2
		Circular Tank	169.3
2	Full	Rectangular Tank	395.2
		Circular Tank	228.3

Bending Moment

Results of bending moment for Rectangular and circular water Tank

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

Table 4.10 Maximum value of Bending Moment in X- Direction

SR. NO	Condition of water tank	Types of tank	MX in KNm
1	Empty	Rectangular Tank	130.5
		Circular Tank	261.2
2	Full	Rectangular Tank	118.3
		Circular Tank	330.2

Table 5.11 Maximum value of Bending Moment in X- Direction

SR. NO	Condition of water tank	Types of tank	MY in KNm
1	Empty	Rectangular Tank	11.2
		Circular Tank	1.71
2	Full	Rectangular Tank	15.1
		Circular Tank	2.57

Table 4.12 Maximum value of Bending Moment in Z- direction

SR. NO	Condition of water tank	Types of tanks	MZ in KNm
1	Empty	Rectangular Tank	175
		Circular Tank	261
2	Full	Rectangular Tank	158
		Circular Tank	330

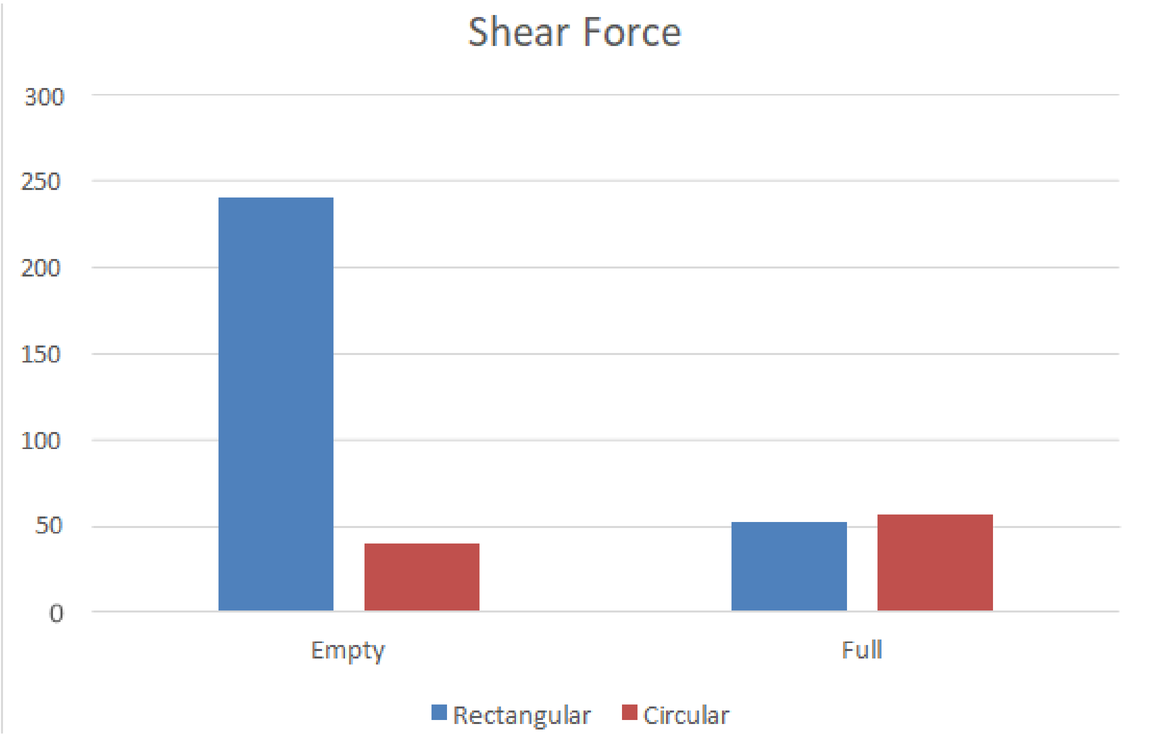

Fig. 4.4 Shear Force for 128000 liters Capacity

IRJMETS
e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

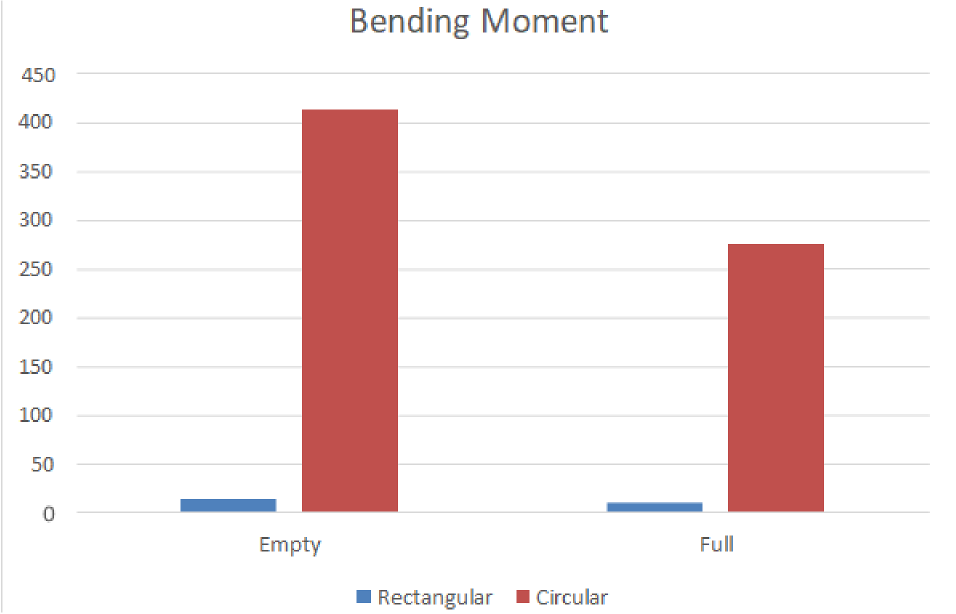

Fig. 4.5 Bending Moment for 128000liters Capacity

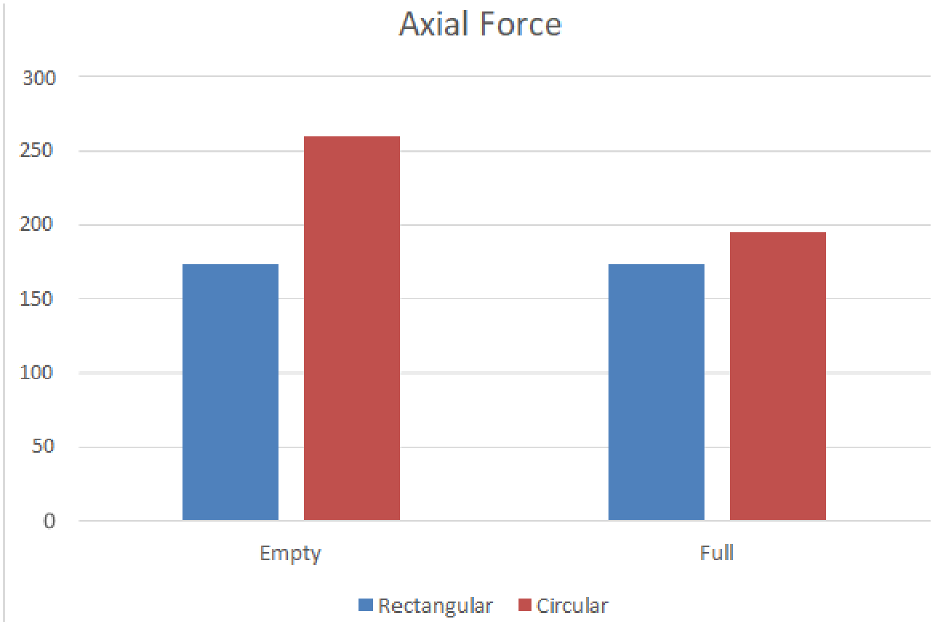

Fig. 4.6 Axial force for 128000 liters Capacity

Comparatively Results of Rectangular and circular water tank for shear force, axial force, bending moment

Comparatively Results of Shear Force for Rectangular and Circular Water Tank

Table 4.13 Comparatively Results of Shear Force

CONDISION	240000liters		120000 litters	
	RectangularTank	Circular tank	RectangularTank	Circular tank
	Shear Force	Shear Force	Shear Force	Shear Force
Empty	102	51	60	36
Full	148	73	84	48

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

Comparatively Results of Axial Force for Rectangular and Circular Water Tank

Table 4.14 Comparatively Results of Axial force

	CAPACITY			
CONDISION	**240000liters**		**120000liters**	
	RectangularTank	**Circular tank**	**RectangularTank**	**Circular tank**
	Axial force	Axial force	Axial force	Axial force
Empty	680	235	395	169
Full	680	282	395	228

Comparatively Results of Bending Moment for Rectangular and Circular Water Tank

Table 4.15 Comparatively Results of Bending Moment

COI- SION	**CAPACITY**											
	240 liter tank capacity						**128 liter tank capacity**					
	RectangularTank			**Circular tank**			**Rectangular Tank**			**Circular tank**		
	MX	MY	MZ	MX	MY	MZ	MX	MY	MZ	MX	MY	MZ
Empty	287	2	350	478	0.0	478	130	10	175	261	1.2	261
Full	276	5	341	527	000	527	118	13	158	330	2.577	330

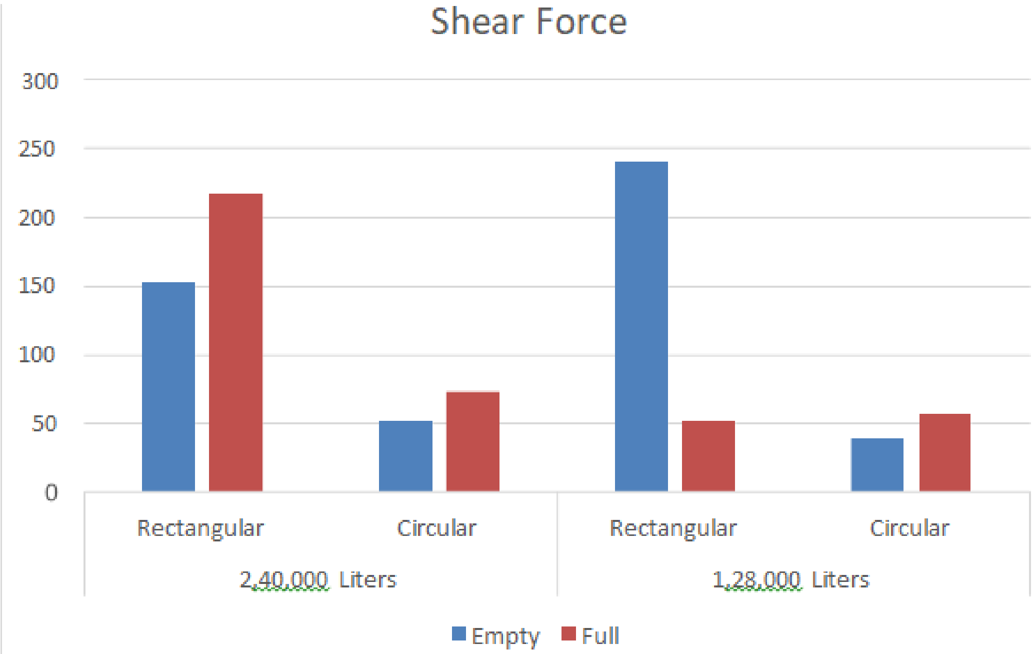

Fig. 4.7 Comparatively Results for Shear Force

V. CONCLUSION

The effect of seismic for rectangular and circular water tank with various load, soil. Variation in loads of tank such as , shear force, bending moment, axial load were considered for the study. The results for rectangular and circular underground water tank with same height different capacity.

The following general conclusions were drawn from the present study.

Comparatively Results of Rectangular and Circular Water Tank Different Shape and Same Capacity

Shear force

- In case of rectangular water tank based on max shear force is obtained as 148 KN in in full tank condition and circular water tank based on max shear force is obtained as 73 KN in full tank condition. More shear force in rectangular water tank compared to that of circular water.
- Max shear force in full tank condition in both rectangular and circular water tank.

Bending moment

- In case of rectangular water tank based on max bending moment is obtained is 350 KNm in empty tank condition and circular water tank based on max bending moment is obtained as 527.7KNm in full tank condition. More moment in circular water tank compared to that of rectangular water tank.
- Max bending moment in empty tank condition in rectangular andfull in circular water tank

Axial force

- In case of rectangular water tank based on max Axial force is obtained is 680 KN in full tank condition and circular water tank based on max Axial force is obtained as 282 KN in full tank condition. More Axial force in rectangular water tank compared to that of circular water.

Note-

- Max shear force in rectangular water tank in full tank condition.
- Max bending moment in circular water tank in full tank condition
- Axial force same in full and empty condition in rectangular and full condition in circular

VI. REFERENCES

[1] D. Gadekar and R. Patel, "Design and Analysis of Under Ground Water Tank Considering Different Fill Conditions Using STAAD . PRO : A Review," vol. 6, no. 1, pp. 11–18, 2022.

[2] G. L. Yisa, "Reliability Analysis of an Underground Reinforced Concrete Rectangular Reliability Analysis of an Underground Reinforced Concrete Rectangular Water Tank," no. February, 2014.

[3] P. R. Chopade and P. O. Modani, "A REVIEW ON COMPARATIVE STUDY OF DESIGN OF WATER TANKWITH IS3370-1965 AND IS3370-2009," pp. 1361– 1365, 2019

[4] K. Kumar and D. Maity, "Pressure Based Eulerian Approach for Investigation of Sloshing in Rectangular Water Tank," Procedia Eng., vol. 144, no. 033, pp. 1187– 1194, 2016,
doi: 10.1016/j.proeng.2016.05.098.

[5] D. Mondal and J. C. Guha, "COMPARATIVE STUDY ON VARIOUS SHAPES OF RCC UNDERGROUND & REST ON GROUND WATER RESERVOIR," vol. 8, no. Iv, pp. 492–497.

[6] V. K. Saha and A. Nim, "Design of RCC Rectangular Water Tank : A Comparative Study Between Design of RCC Rectangular Water Tank : A Comparative Study Between Approximate and IS Code Method .," no. January 2019, 2022, doi: 10.2139/ssrn.3353083.

[7] A. Nimade, "Parametric Study of Underground Water Tank using FEM," vol. 4, no. 09, pp. 94–98, 2018.

[8] K. Region-iraq, K. Region-iraq, A. H. Consultant, and U. A. Emirates, "A COMPARATIVE STUDY OF REAL FULL SCALE GROUND," vol. 32, no. 2, pp. 157–172, 2020.

[9] A. A. Bhende and P. B. Jamale, "Comparative Analysis of Different Shapes of Underground Water Tank," vol. 1, no. 5, pp. 19–21, 2022.

[10] V. S. Navane and S. N. Sahoo, "A review of integrated RS and GIS technique in groundwater potential zone mapping. pp. 1–10, 2017.

[11] V. Singh, V. K. Gupta, S. Tiwari, S. Vaishnav, and V. Vishwavidyalaya, "Seismic Analysis of Existing Underground Water Tank Using ETABS," vol. IV, no. Ii, pp. 9–14, 2022.