Comparative Seismic and Cost Analysis of RCC Circular, Rectangular and Intze Elevated Water Tank

Tiruveedhula Chandana, S.V. Surendhar

Abstract*: This paper presents the study deals with the performance of elevated reinforced concrete overhead water tanks to seismic and wind forces. An elevated overhead water tank is a storage structure constructed at a certain elevation to hold water and supply safe drinking water. It is a time-consuming task to design and cost estimation of overhead water which have needs lot of expertise. These elevated water tanks are especially vulnerable to horizontal forces such as wind and earthquakes. Tanks of various shapes are considered in the present study. Circular, Rectangular and Intze Elevated water tanks are modelled in STAAD.PRO software. Gravity analysis, Seismic analysis and wind analysis are performed on the modelled structure. From the analysis results, the seismic parameters such as displacements, base shear and over turning moments are examined deeply and compared and cost analysis is performed for all the three water tanks and compared.

***Index Terms*: Elevated Water Tanks, Gravity Analysis, Seismic Analysis, Wind Analysis, Cost Analysis.**

I. INTRODUCTION

In developing countries, the safe supplying of portable water and enough water are most significant needs. At present still there is a big shortage of pure water distribution and supplying in rural areas. Most of the people in developing countries are relay on rivers, natural springs, water supply schemes with limited pipes and available man-made wells. The most of cases dwellings are not available in considerable distances. The efficiency of piped water distribution builds up on the provision of water storage tanks [1]. In small cities or in developing areas, it is used to store water in 2 to 50 mega liters concrete water reservoirs or even higher as "surge" or "header" tanks with constant head from a remote reservoir and stored water supplied to a selected community [2].

For supplying drinking water safety reinforced concrete elevated water tanks are utilized. With rapid developments, interest for drinking water was expanded by numerous folds. Likewise, because of deficiency of power, it is beyond the realm of imagination to expect to distribute water over pipes at peak timings. In such circumstances overhead water tanks shift a key piece of daily life. As interest for water tanks can keep on expanding in coming years, speedy cost forecast of tanks before its structure will be useful in choice of tanks for genuine plan. Keen expense expectation of tanks of various geometry and limit is a troublesome activity and a tedious errand particularly for less experienced plan engineers [3-4]. Commonly, it is required to know the expense of a tank of known limit and geometry before its point by point plan [5]. In [2] and [6-10] have likewise added to the solidness and the economy of water tank plan.

An elevated water tank is a storage structure constructed at a certain elevation in order to hold water and to provide a required water pressure in the distribution of water for different needs. In general, elevated water tanks are extensively used by municipalities for storage and supply of water for certain location. These elevated water tanks consist of large mass of water stored on the top of few slender columns, therefore it is a critical case to consider during earthquakes. These elevated water tanks are especially vulnerable to horizontal forces such as wind and earthquake. As elevated water tanks are being constructed even in high seismic zones, it is essential to ponder the seismic conduct of elevated water tank in detail.

In the present study, the behavior of three types of RCC water tanks under seismic influence is studied. The three elevated water tanks namely Circular, Rectangular and Intze water tanks are modelled and analyzed using STAAD.PRO software. From the analysis results, the seismic parameters such as Displacements, Base shear and overturning moments are studied and compared. In addition to that, cost analysis is done for all the three types of water tanks and is compared.

II. TYPES OF WATER TANK

In present year, there has been much accentuation on water supply extends everywhere throughout the world, which are exceptionally fundamental for the social and modern improvement of the nation. Capacity difference of water tanks can be accessible relying on the necessity of utilization. The water tanks are classified based on shape:

a. Rectangular tanks
b. Circular tanks
c. Intze tanks
d. Spherical tanks
e. Circular tank with conical bottom.

Revised Manuscript Received on June 05, 2019

Tiruveedhula Chandana, Department of Civil Engineering, Vignan's University, Vadlamudi, Guntur (Dist.), Andhra Pradesh, India.
S.V. Surendhar, Department of Civil Engineering, Vignan's University, Vadlamudi, Guntur (Dist.), Andhra Pradesh, India.

Also, there is three ways of water tanks classified based on the location:

a. Tank resting on grounds
b. Underground water tanks
c. Elevated or overhead water tanks.

III. OBJECTIVE

The objectives of the current study are:

- To perform Gravity analysis for Circular, Rectangular and Intze Elevated water tank.
- To perform Seismic analysis for Circular, Rectangular and Intze Elevated water tank.
- To perform Wind analysis for Circular, Rectangular and Intze Elevated water tank.
- To do cost comparison amongst the Circular, Rectangular and Intze Elevated water tank.
- To study Impulsive and convictive forces for Circular, Rectangular and Intze Elevated water tank.
- To compare the results of both wind analysis and seismic analysis to check which forces are predominant on which type of water tank.

IV. METHODOLOGY

Three water tanks namely Circular, Rectangular and Intze water tank are modelling using STAAD.PRO software. The three tanks have same water capacity i.e., 1000KL. The same is designed for both seismic and wind analysis. The design procedure involves Gravity analysis, Equivalent Static analysis and Wind analysis. The results were obtained and tabulated in Microsoft excel. The concrete design is done as per the codal provisions of IS 456:2000. Equivalent static analysis is carried out with the help of IS 1893:2002 (Part -1) codal provisions and wind analysis data is taken from IS 875 Part 3. Both the analyses were carried out individually in separate models and their results were tabulated. The efficiency of the three water tanks is studied from the results.

V. MATERIAL PROPERTIES

The material properties [11-13] which are used in modelling of the water tank in STAAD.PRO software are described below:

- The grade of concrete which is used for elevated frame section is : M30
- The grade of steel concrete which is used for elevated frame section is : fe500
- Capacity of all the three water tanks is : 1000KL
- Diameter of intze, circular water tank is 14.8 m
- Thickness of Dome for all the three water tanks is : 150 mm
- Thickness of water tank wall for all the three water tanks is : 250 mm
- Density of Brick is : 20 kn/m³
- For circular and rectangular tanks Beam dimension is : 0.45 x 0.35 m
- For Intze water tank ring beams dimension is: 0.55 x 0.8 m
- For all tanks column dimension is : 0.5 m
- Height of Intze, circular tanks top dome: 2m
- Height of Intze tank cylindrical wall: 4.5 m
- Height of Intze tank bottom dome: 2.2 m
- Height of circular tank wall: 7 m
- Dimensions of rectangular tank: 12 x 12 x 8 m

VI. DESIGN DATA

A. Comparison of Seismic Analysis and Wind Analysis

In Seismic analysis and wind analysis of different elevated water tanks**,** Table 1, Table 2 and Table 3 gives the details with respect to each axis's dimension values considered in seismic and wind analysis respectively for Maximum base shear, Maximum displacement and Maximum overturning moment respectively.

Table 1 Axis detail for various tanks for Base shear for Seismic Analysis and Wind Analysis

	Seismic Analysis		Wind Analysis	
Tank	**X**	**Z**	**X**	**Z**
Circular	162	162	80.47	80.47
Rectangular	435	435	114.16	114.16
Intze	394	394	57.09	57.09

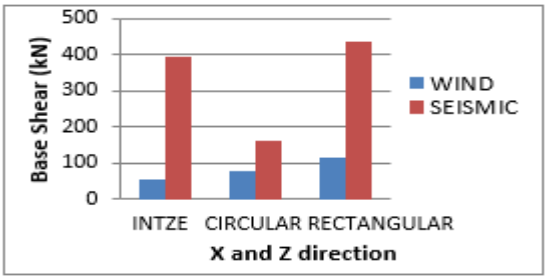

Fig. 1 Comparison Seismic and Wind Analysis for Base Shear Values of various tanks

Table 2 Axis detail for various tanks for Maximum Displacement for Seismic Analysis and Wind Analysis

	Seismic Analysis		Wind Analysis	
Tank	**X**	**Z**	**X**	**Z**
Circular	8.134	0.8134	1.89	1.89
Rectangular	15.81	1.58	2.46	2.46
Intze	20.79	2.079	0.82	0.82

Table 3 Axis detail for various tanks for Maximum overturning for Seismic Analysis and Wind Analysis

	Seismic Analysis		Wind Analysis	
Tank	**X**	**Z**	**X**	**Z**
Circular	1148	1148	611.3	611.3
Rectangular	1465	1465	692.38	692.38
Intze	1020	1020	483.28	483.28

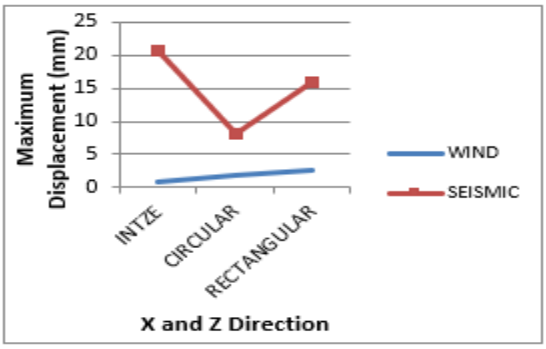

Fig. 2 Comparison Seismic and Wind Analysis for Maximum displacement Values of various tanks

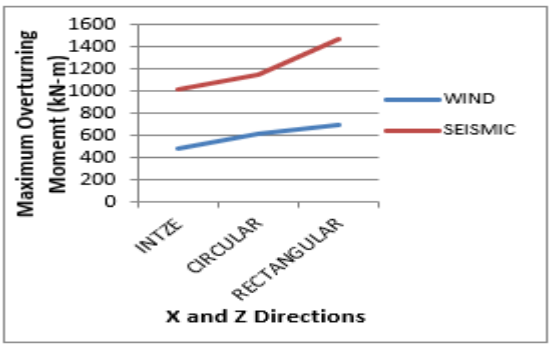

Fig. 3 Comparison Seismic and Wind Analysis for Maximum overturning moment of various tanks

Table 4 Comparison Seismic and Wind Analysis results of Beams for various tanks

Beams	Seismic Analysis			Wind Analysis		
	Axial Force (kN)	Moment in Y (kN-m)	Moment in Z (kN-m)	Axial Force (kN)	Moment in Y (kN-m)	Moment in Z (kN-m)
Circular	128.99	18.384	141.533	128.99	18.384	141.533
Rectangular	151.73	27.736	164.606	141.74	27.736	52.864
Intze	1286.61	11.178	279.854	1286.61	6.32	240.006

Table 5 Comparison Seismic and Wind Analysis results of Column for various tanks

Columns	Seismic Analysis			Wind Analysis		
	Axial Force (kN)	Moment in Y (kN-m)	Moment in Z (kN-m)	Axial Force (kN)	Moment in Y (kN-m)	Moment in Z (kN-m)
Circular	6302.51	298.452	298.452	6302.51	245.584	245.584
Rectangular	2506.91	175.679	175.679	2506.91	73.912	111.348
Intze	1447.76	241.397	241.397	1201.55	123.882	123.882

Table 6 Comparison Seismic and Wind Analysis Design results of Beams for various tanks

Type of tank	Seismic Analysis				Wind Analysis			
	Beam. no	C/S of beam	Area of reinforcement (mm^2)		Beam. no	C/S of beam	Area of reinforcement (mm^2)	
			Top	Bottom			Top	Bottom
Circular	1320	350x450	977	933	**1320**	**350X450**	**977.16**	**933.42**
Rectangular	861	350x450	1073	969	**128**	**350X450**	**439.46**	**436.67**
Intze	1316	550x800	945	715	**1311**	**550X800**	**943.99**	**715.28**

Table 7 Comparison Seismic and Wind Analysis Design results of Beams for various tanks

Type of Tank	Seismic Analysis			Wind Analysis		
	Column number	Diameter of column	Percentage Of steel required (mm^2)	Column number	Diameter of column	Percentage Of steel required (mm^2)
Circular	1256	650	2.5% of c/s area	**1256**	**650**	**2.65% of c/s area**
Rectangular	884	550	0.81% of c/s area	**884**	**550**	**0.81% of c/s area**
Intze	2409	550	0.81% of c/s area	**2416**	**550**	**0.81% of c/s area**

Maximum base shear values, Maximum displacement and maximum overturning moment from the equivalent static method (Seismic Analysis) and Wind Analysis in STAAD.PRO software is obtained, and comparisons are shown in the Fig. 1, Fig. 2 and Fig. 3 respectively. Table 4 and Table 5 shown the comparison of the Seismic and Wind Analysis results for beams and columns respectively and Table 6 and Table 7 shown the comparison of the Seismic and Wind Analysis design results for beams and columns respectively. From Seismic analysis and wind analysis, it is observed that circular tank has good. The cost estimation values are given in the Table 8 and observed that circular elevated tank cost estimation is less compared with Intze and rectangular elevated tanks. Previous researchers [14-18] are not compared the three types of tanks and with respect to seismic and wind analysis results along with the cost estimation.

Table 8 Cost estimation of different elevated water tanks

Type of Tank	Cost Estimation (Rs.)
Intze	19,48,733/-
Rectangular	17,98,444/-
Circular	11,88,714/-

I. CONCLUSIONS

From the above results, the following conclusions has been observed

- Taking the shape and geometry, over-turning moment is found to be greater in rectangular water tank when compared to the other two water tanks (Circular and Intze).
- Under seismic loading, Circular water tank is recommended.
- Under wind loading, Intze water tank is recommended.
- Circular water tank experiences greater displacement when compared to other two water tanks due to its support conditions.
- Circular water tank experiences greater base shear when compared to Rectangular and Intze water tanks.
- Comparing seismic analysis and wind analysis results, Intze water tank is recommended.
- As per cost analysis, Circular water tank is found to be economical when compared to the other two tanks. extensions.

REFERENCES

1. L.M. Shirima, “Reinforced Blockwork Water Storage Tanks- Reaching The Unreached: Challenges For The 21st Century”, 22nd WEDC Conference, New Delhi, 1996.
2. Patentscope, “Construction of Liquid Retaining Structures”, 1998. www.wipo.int/patentscope/en/.
3. K.K. Pathak and R. Agarwal, “Cost Prediction of Overhead Water Tanksusingartificial Neural Networks”, IE (I) Journal , Vol. 84, 2003, pp. 153 – 158.
4. A. Pall, and R.T. Pall, “Performance-Based Design Using Pall Friction Dampers- An Economical Design Solution”. Paper No. 1955. 13th World Conference on Earthquake Engineering. Canada, 2004.
5. W.M. Slater, “Concrete Water Tanks in Ontario”. Canadian Journal of Civil Engineering, Toronto, 1985.
6. W.S. Gray and G.P. Manning, “Water Towers, Bunkers, Silos and Other Elevated Structures”. London. Concrete Publications Limited, 1964.
7. A. Ludwig, “Tanks, Cisterns, Aquifers, and Ponds. For Domestic Supply, Fire and Emergency, 2008.
8. G.P. Manning, “Reservoirs and Tanks. London. Concrete Publications Limited, 1967.
9. D. Elliott, “Wondering About Water Towers” New York Times, 2006.
10. J. Charles, “Longtime Emblems of City Roofs, Still Going Strong” , The New York Times, 2007.
11. IS: 1893-1984 “Criteria for Earthquake Resistant Design of Structures”.
12. IS:1893(2002) “Criteria for Earthquake Resistant Design of Structures”.
13. IS.11682.1985 "criteria for design of rcc staging for overhead water tanks”
14. Soheil Soroushnia, Sh.Tavousi Tafreshi, F. Omidinasab, N. Beheshtian, Sajad Soroushnia, “Seismic Performancof RC Elevated Water Tanks with Frame Staging and Exhibition Damage Pattern”, Procedia Engineering, Vol. 14, 2011, pp. 3076-3087
15. W.O. Ajagbe, S.I. Adedokun, and W.B. Oyesile, “Comparative Study on the Design of Elevated Rectangular and Circular Concrete Water Tanks”, International Journal of Engineering Research and Development, Vol. 1, No. 1, 2012, pp. 22-30
16. M.V. Krishna Rao, P. Rathish Kumar and K. Divya Dhatri, "Seismic analysis of overhead circular water tanks – a comparative study", IJRET: International Journal of Research in Engineering and Technology, Vol. 4, No. 1, 2014, pp. 74-83
17. N. Mangulkar Madhuri and V. Gaikwad Madhukar, "Review on seismic analysis of elevated water tank", International Journal of Civil Engineering and Eechnology (IJCIET), Vol.6, No. 5, 2017, pp. 202-208
18. J. Yogeshwarana and C.Pavithra, “Behaviour of an elevated RC tank subjected to various Earthquake responses” International Journal of Engineering Trends Technology (IJETT), Vol. 21, No. 9, March 2015, pp. 440-444.

AUTHORS PROFILE

Tiruveedhula Chandana received her B.Tech degree in Civil Engineering from JNTU, Kakinada in 2017 and pursuing M.Tech degree in Structural Engineering from Vignan’s University. Her research interest including AutoCAD design, structure design.

S.V.Surendhar from Tamilnadu, received Post Graduation (Structural Engineering) from IIIT Hyderabad. Working as Asst. Professor in VFSTR University, Vadlamudi, Guntur, Andhra Pradesh.