Time History Analysis of Circular and Rectangular Elevated Water Storage Tank using Baffle Wall

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ABSTRACT

In the world, there are large number of storage tanks which are used as water and oil storage facilities. Elevated water tank is one of the most important structures in earthquake event. As known from very upsetting experiences, elevated water tanks were heavily damaged or collapsed during earthquake Hence different configurations of liquid storage tanks have been constructed. Water tanks are play an important role in municipal water supply and firefighting systems. Due to post earthquake useful desires, seismic safety of water tanks is most important. In the current study time history analysis of rectangular and circular elevated water storage tank were analyzed using SAP 2000 software. In this study the concrete baffle wall was used to reduce sloshing effect of the water tank. The tank responses such as maximum nodal displacement, base shear and result were compared for empty and full tank water fill condition. From IS 11682:1985provision when seismic loading is considered only two cases may be taken one is tank empty condition and other is tank full condition. Finally, study discloses the importance of suitable supporting baffle wall to remain withstand against heavy damages of circular and rectangular elevated water tanks during earthquake. As per IITK-GSDMA guidelines for seismic design of liquid storage tanks, hydrodynamic pressure for impulsive and convective mode was calculated.

***Keywords*—** Elevated Water Tanks, Time History Analysis, Baffle Wall, SAP 2000

I. INTRODUCTION

Water tanks are very important for open utility and for modern structure, numerous new thoughts and development has been made for the capacity of water in various structures and forms. Baffle wall is wall which is constructed from concrete as well as fiber material. Lightweight, high strength fiber glass baffle panels are ideal for water flow control application. Baffles can be mounted to existing columns and attached to I-beams or attached to concrete walls with clip angles. According to seismic code IS: 1893 (Part I):2016 more than 60% of India is prone to earthquake. The seismic design of the liquid storage tanks needs knowledge of hydrodynamic pressure distribution on the walls, resulting forces and moment as well as the sloshing of contained liquid. Freeboard is generally provided to allow liquids to slosh freely inside to prevent sloshing impact on the tank roof. The elevated water tank is a huge water storage container developed to hold water supply at certain tallness to pressurize the water appropriation framework. During Bhuj and Koyna earthquake, many tanks suffered typical damage such as fire, buckling of floating roofs, caving of fixed roofs and failure on structural systems on tanks, even if location is about far from the epicenter. Seismic behavior of elevated tanks should be investigated in detail since these tanks are frequently used in seismic zone III because Koyna comes in Pune region and their seismic zone is III. In the past earthquakes including Koyna earthquake of 11 Dec 1967, damages had been observed widely in support structures. Liquid storage tanks are subject to the risk of damage due to earthquake vibrations. Due to lack of knowledge of the support systems, many of the water tanks collapsed or were damaged.

1.1 Objectives

- To study the behavior of circular and rectangular elevated water storage tank by using Koyna(1967) earthquake time acceleration records.
- To conduct time history analysis of circular and rectangular water storage tanks when the tank is empty and completely filled.
- To study seismic behavior of circular and rectangular water tank with and without baffle wall.
- To compare the response histories such as maximum displacement and base shear using baffle wall.

II. MODEL PROVISIONS

The movement of water with respect to tank and movement of tank with respect to ground was accounted by Housner G.W. which demonstrates an predetermined dynamic examination for the reaction of lifted water tanks to tremor ground movement and it has additionally been called attention to that if a closed tank is totally loaded with water or totally vacant, it is basically a one mass structure and if the tank has a free water surface, there will slosh of the water amid an earthquake and this makes the tank basically a two mass structure. The pressure generated within the fluid due to the dynamic motion of the tank can be separated into impulsive and convective parts. At the point when a tank containing fluid with a

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free surface is subjected to level of earthquake ground movement, tank wall and liquid are subjected to horizontal acceleration. Two mass model idealization of the elevated water tank is more appropriate as compared to a one mass idealization model and it is being commonly used in most of the international codes and also in IS code 1893(Part 2):2014.

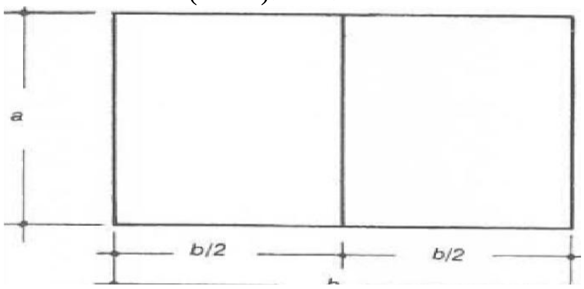

Figure 1: General geometric plan features of the double containment of tanks

In this study the typical single-compartment to elevated water tanks used. The general geometric features of the tanks, considered for the study. Figure 1 shows the minimum length of the tank's wall (to minimize the amount of required construction materials) for a given tank's area. If a liquid tank vibrates along with liquid, the liquid exerts both impulsive as well as convective hydrodynamic pressure on tank wall. The liquid in the lower region of the tank behaves like a mass that is rigidly connected to wall. This mass is termed as impulsive liquid mass and liquid mass in the upper region of the tank this mass is termed as convective liquid mass. However, for most of elevated tanks it is observed that both the time periods are well separated. Hence, the two-mass idealization are often treated as two uncoupled single degree of freedom system as shown in fig 2. Thus, total mass is divided into two parts impulsive mass and convective mass. In spring mass model convective massis attached to the wall by the spring having stiffness, whereas impulsive massis rigidly attached to the tank. The various parameters of this model depend upon geometry and flexibility of tank.

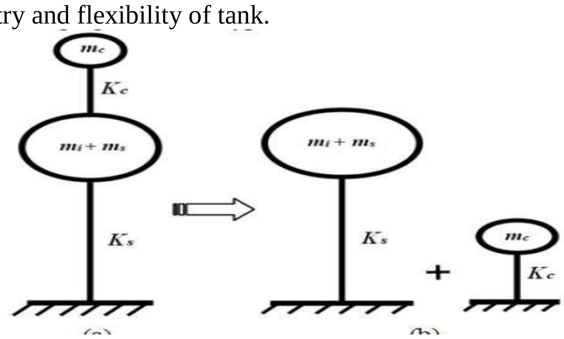

Figure2: Two mass idealization

III. METHODOLOGY

This methodology includes the selection of water tank types such as rectangular water tanks and circular water tanks, improving the component dimensions for selected water tanks and carrying out a non-linear time history analysis using IS 1893 (Part 1): 2016 and IS 1893 (Part 2): 2014 code concept. Time-History analysis is a well-ordered strategy where the loading and the response history are assessed at progressive time increases. The function values in a time history function to be normalized ground acceleration values and they may be multiplying for specified (displacements and velocities) load pattern and the loading history in the interval. Time history analysis uses the blend of ground movement records with detailed structural auxiliary model accordingly it is equipped for creating comes about with generally low vulnerability. It is the dynamic nonlinear analysis in which the loading causes critical changes in stiffness.

In this strategy the structure is subjected to genuine ground movement records. This makes examination technique and very unique in relation to all of different analysis strategies as the inertial forces are specifically decided from these ground movements or in forces are calculated as capacity of time, to taking dynamic properties of structure. A time history function might be a list of time and function esteems or only a list of function values that are assumed to occur at equally spaced interval. The capacity esteems in a period history capacity might be standardized ground speeding up qualities or they might be multipliers for indicated (power or relocation) stack work. It is an examination of dynamic reaction of the structures at every augmentation of time, when its base is subjected to particular ground movement. In this analysis the load combinations are to be design as per IS 1893(Part 1): 2016.In seismic loads factors such as zone factor, important factor, response reduction factor and damping ratio are used for time history analysis. Response reduction factor is dependent on type of frame used. All seismic parameters are used as per IS 1893(Part1): 2016, 1893 (Part 2):2014 and IITK-GSDMA guidelines for seismic design of liquid storage tanks.

Table 1-Seismic parameters used for elevated water storage tank

Constant	Values	Remarks
Z	0.16	Water tank in zone III
I	1.5	Importance factor
R	4	Response reduction factor

Table2-Properties of Koyna earthquake ground motion

Earthquake	Magnitude (Richter scale)	Duration (sec)	PGA (g)
Koyna (1967)	6.5	13.38	0.36g

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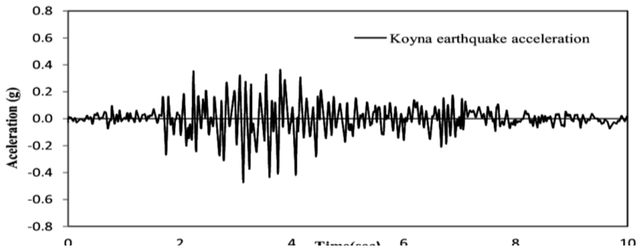

Figure3: Koyna earthquake (1967) acceleration time history data

IV. NUMERICAL SIMULATION OF THE WATER TANK

This research was conducted on circular and rectangular elevated water storage tank using baffle wall. The capacity of elevated water storage tank is taken as 1.65 lac litres with staging height of 16 m and 4m height of each panel in this analysis. There are 180mm concrete baffle wall used in water tank. The staging is acting like a bridge between container and foundation for the transfer of loads acting on the tank. The six-column staging has been considered as a numerical problem in both circular and rectangular water tank. In the case of water tank full condition, the maximum hydrodynamic pressure for circular tank is about 2.97 kN/m² and for rectangular tank 3.24 kN/m² acing on tank side wall. The hydrostatic pressure for both tanks is about 36.297 kN/m² acting on base of the floor slab. Table 3 and Table 4 shows the dimensions and various parameters of circular and rectangular elevated water storage tank.

Table3- Parameters of rectangular water tank

Component	**Size**
Length	9 m
Breadth	4.5 m
Roof Slab Thickness	120 mm
Roof Beam Size	230 mm x 300 mm
Tank Wall Thickness	200 mm
Floor Slab Thickness	200 mm
Floor Beam Size	230mm x 600mm
Size of Braces	230 mm x 350 mm
Size of Column	230mm x 650mm
Number of Columns	6
Size of Baffle Wall	180mm
Height of Tank	4m
Staging Height	16 m
Free Board	0.3 m
Grade of Concrete	M25, M30
Grade of Steel	Fe 415
Earthquake Zone	III
Soil Type	Medium Soil

Table4- Parameters of circular water tank

Component	**Size**
Diameter of Tank	7.25 m
Roof Slab Thickness	120 mm
Roof Beam Size	230 mm x 230 mm
Tank Wall Thickness	200 mm
Floor Slab Thickness	200 mm
Floor Beam size	230 mm x 600 mm
Size of Braces	230 mm x 350 mm
Column Diameter	400 mm
Number of Columns	6
Size of Baffle Wall	180 mm
Height of Tank	4 m
Staging Height	16 m
Free Board	0.3 m
Grade of Concrete	M25, M30
Grade of Steel	Fe 415
Earthquake Zone	III
Soil Type	Medium Soil

V. 3D MODELS OF WATER TANK

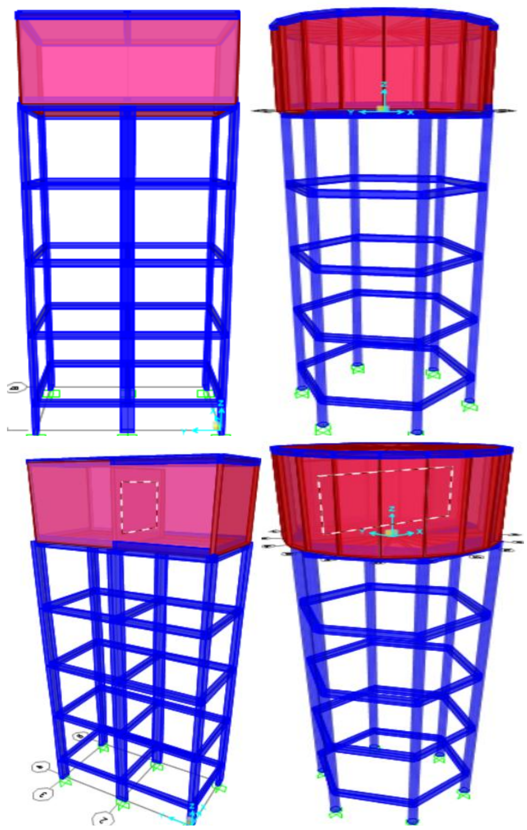
Figure4: 3D Models of Circular and Rectangular Water Storage Tank (with and without baffle wall)

VI. RESULT & DISCUSSIONS

The rectangular and circular elevated water storage tanks with and without baffle wall systems as shown in figure 4. It has been analyzed by using the SAP 2000 software as per IS provisions. From the analysis results for different important properties like maximum top node displacement and base shear has been obtained and presented in table6andtable8.Top node displacement

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results are obtained for the joint 4 to the circular water tank and joint 9 to the rectangular water tank. The time period of the impulsive and convective mode was also obtained for the empty and full circular and rectangular tanks, as indicated in Tables 5 and 7, but in the case of empty tank conditions will not take convective vibration modes according to IITK-GSDMA (2007) guidelines for design seismic liquid storage tank. This result may be due to the fact that the hydrodynamic pressures of container consider only in tank in full condition.

6.1 For Rectangular Water Tank

- The top nodal displacement decreases comparing without baffle wall water tank to with baffle wall by 14.55% in empty tank and 6.24% in full tank condition.
- The base shear increases comparing without baffle wall water tank to with baffle wall by 19.36%in empty tank and 19.78% in full tank condition.
- Time period increases for both empty tank and full tank condition as well as convective time period is constant in with baffle wall as compared to without baffle wall.

Table 5-Time period of rectangular elevated water storage tank in empty and full condition

Tank System	Time Period Empty Condition [sec]	Time Period Full Condition	
		Impulsive Time Period [sec]	Convective Time Period [sec]
Without Baffle Wall	0.425	0.529	3.639
With Baffle Wall	0.439	0.541	3.639

Table 6-Results of nodal displacement and base shear

Tank System	Displacement (mm)		Base Shear (kN)	
	Empty Tank	Full Tank	Empty Tank	Full Tank
Without Baffle Wall	22.68	23.34	61.18	57.64
With Baffle Wall	19.38	21.93	75.87	71.86

6.2 For Circular Water Tank

- The top nodal displacement decreases comparing without baffle wall water tank to with baffle wall by 8.05% in empty tank and 9.10% in full tank condition.
- The base shear increases comparing without baffle wall water tank to with baffle wall by 13.02% in empty tank and 20.88% in full tank condition.
- Time period increases for both empty tank and full tank condition as well as convective time period is constant in with baffle wall as compared to without baffle wall.

Table 7-Time period of circular elevated water storage tank in empty and full condition

Tank System	Time Period Empty Condition [sec]	Time Period Full Condition	
		Impulsive Time Period [sec]	Convective Time Period [sec]
Without Baffle Wall	0.474	0.615	3.60
With Baffle Wall	0.484	0.623	3.60

Table 8- Results of nodal displacement and base shear

Tank System	Displacement (mm)		Base Shear (kN)	
	Empty Tank	Full Tank	Empty Tank	Full Tank
Without Baffle Wall	22.10	23.61	58.22	52.05
With Baffle Wall	20.32	21.46	66.94	65.79

VII. CONCLUSIONS

The circular and rectangular elevated water tanks were analyzed using SAP 2000 and the following conclusions were obtained as follows.

1. The baffle wall is less displacement and more base shear as compared to the without baffle wall simple water tank in rectangular and circular water tank for empty and full tank condition.
2. The time period increases with baffle wall as compared to the without baffle wall in rectangular and circular water tank due to the increase in mass of the tank.
3. The convective time period remains constant in both circular and rectangular water tank. This implies that the convective mode doesn't depend on staging and eventually depends on the size of the tank.
4. The time period varies in tank empty condition and tank full condition, this is due to the sloshing effect and hydrodynamic pressure.

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REFERENCES

[1] Dhanya Johnson & Dr. M. Sirajuddin. (2018). Behavior of elevated water tank under seismic load–Review. *International Research Journal of Engineering and Technology, 05*(05), 3196-3200.

[2] Sayed H. Haqbin, ChintanD. Patel, & Bansal R. Patel. (2017). Seismic analysis of RC elevated rectangular water tank using IS 1893 (Part2): 2006 draft code. *International Journal of Advanced Research, 5*(2), 1831-1840.

[3] Uma Maheswari & B. Sravani, (2016). Performance of elevated circular water tank in different seismic zones. *International Journal for Technological Research in Engineering, 03*(05), 2347–4718.

[4] Sushil Gupta & I. D. Gupta. (2004). The prediction of earthquake peak ground acceleration in Koyna region, INDIA. *World Conference on Earthquake Engineering Vancouver, B.C., Canada, Paper No. 1437*, pp. 1-6.

[5] Professor. Sudhir K. Jain. (1998). Indian earthquakes: An overview. *The Indian Concrete Journal, 72*(11). Available at: https://www.iitk.ac.in/nicee/skj/publications.htm.

[6] G. W. Housner. (1963). The dynamic behaviour of water tanks. *Bulletin of the Seismological Society of America, 53*(2), 381-387.

[7] Sonali M. Pole & Amey Khedikar. (2017). Seismic behaviour of elevated water tank under different staging pattern. *International Journal of Engineering and Management Research, 7*(3), 199-205.

[8] IS: 1893-2016 (Part I). Criteria for earthquake resistant design of structure. *Bureau of Indian Standards, New Delhi*. Available at: https://bis.gov.in/other/quake.htm.

[9] IS: 1893-2014 (Part II). Criteria for earthquake resistant design of structure (Liquid retaining tanks). *Bureau of Indian Standards, New Delhi*. Available at: https://bis.gov.in/other/quake.htm.

[10] IS: 11682-1985. Criteria for design of RCC staging for overhead water tanks. *Bureau of Indian Standards, New Delhi*. Available at: http://www.questin.org/sites/default/files/standards/is.11682.1985_0.pdf.

[11] IS: 3370-2009 (Part I). Concrete structures for storage of liquids. *Bureau of Indian Standards, New Delhi*. Available at: https://archive.org/stream/gov.in.is.3370.2.2009/is.3370.2.2009_djvu.txt.

[12] IS: 3370-2009 (Part II). Concrete structures for storage of liquids (Reinforced concrete structures). *Bureau of Indian Standards, New Delhi*. Available at: https://dokumen.tips/documents/dg-ws-102-r-2010-11-kmc-dated-19102010-kolkata-municipal-corporation.html.

[13] IITK-GSDMA (2007). Guidelines for seismic design of liquid storage tanks. *National Information Centre for Earthquake Engineering, IIT Kanpur*. Available at: http://www.iitk.ac.in/nicee/IITK-GSDMA/EQ08.pdf.

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