SEISMIC ANALYSIS OF ELEVATED RCC WATER TANKS HAVING DIFFERENT CAPACITIES

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***Abstract*— It is known that, some of the fluid containers are damaged in many earthquakes. Damage or collapse of these containers causes some unwanted events such as shortage of drinking and utilizing water, uncontrolled fires and spillage of dangerous fluids. Even uncontrolled fires and spillage of dangerous fluids subsequent to a major earthquake may cause substantially more damage than the earthquake itself. Due to these reasons this type of structures which are special in construction and in function from engineering point of view must be constructed well to be resistant against earthquakes.**

The object of the present work is to compare the seismic behaviour of elevated square and circular RCC water tanks having different capacities of storage. For this purpose square and circular elevated water tanks of capacities 1 lakhs and 2 lakhs are considered to analyse under seismic forces. Heights of staging considered are 12m, 18m and 24m for square and circular tanks for both the capacities. All the models are analysed for zone III, zone IV and zone V using Staad.Pro v8i software. To study the seismic behavior of both the tanks the response parameters selected are lateral displacement and base shear.

Observation shows that the provision of circular water tank is more flexible for seismic loadings as compared to square water tank. From the analysis result parameters deflection and base shear of the water tanks increases from lower to higher zones because the magnitude of intensity will be more for higher zones.

Present work provides good information on the result parameters deflection and base shear in the water tanks having different staging heights.

***Keywords*— Water Tank, Square, Circular, Deflection, Base Shear.**

I. INTRODUCTION

A huge water storage container is said to be an elevated water tank which is constructed for supplying the water at certain height for the water distribution system. There are different ways for the storage of liquid such as underground, ground supported and elevated used extensively by municipalities and industries. Hence water tanks are most important for public usefulness and for industrial structures. Elevated water tanks consist of huge water mass at the top of a slender staging which is most critical consideration for the failure of the tank during earthquakes. These are the most important and special structures; and during earthquakes damaging of these structures may cause danger to drinking water supply, fail in preventing large fires and may cause substantial economic loss. Water is human basic needs for daily life. In certain area sufficient water distribution depends on the design of a water tank. Water supply depends on overhead water tanks for storage in our country as the required pressure in water supply process is obtained by gravity in elevated tanks rather than the need of heavy pumping facilities. Due to natural disasters like earthquakes, draughts, floods, cyclones etc Indian sub-continent is highly vulnerable. According to seismic code IS: 1893 (Part 1)-2002, more than 60% of India is prone to earthquakes. During earthquake for the failure of elevated water tanks it is most critical consideration that huge water mass is at top of a slender staging. Since, the elevated tanks are frequently used in seismic active regions also hence their seismic behavior has to be investigated in detail.

Fig. 1 Types of water tanks

Based on the location of tank in a building, tanks can be classified into three categories:

1. Tanks resting on ground
2. Underground tanks
3. Overhead tanks

The tanks resting on ground like clear water reservoirs, settling tanks etc. are supported on the ground directly. The walls of these tanks are subjected to pressure and the base is subjected to weight of water and pressure of soil. The tanks may be covered on top.

The examples of underground tanks are as septic tanks, purification tanks, Imhoff tanks, and gas holders. The walls of these tanks are subjected to water pressure from inside and the earth pressure from outside. The base is subjected to weight of water and soil pressure. At the top these tanks are covered.

Elevated or overhead water tanks are supported on staging which might consist of masonry walls, R.C.C. tower or R.C.C. columns braced together. The walls are subjected to water pressure. The base has to carry the load of water and tank load. The staging has to carry load of water and tank. The staging is also designed for wind forces.

From the shape point of view water tanks may be of several types:

1. Circular tanks
2. Circular tanks with conical bottoms
3. Rectangular tanks

Circular tanks are usually good for very larger storage capacities the side walls are designed for circumferential hoop tension and bending moment, since the walls are fixed to the floor slab at the junction. The co-efficient recommended in IS 3370 part 4 is used to determine the design forces. The bottom slab is usually flat because it's quite economical.

Circular tank with conical bottoms is best in architectural feature and aesthetic this tank has another important advantage that its suitable for high staging the tank's hollow shaft can be easily built. It can be economical and rapidly constructed using slip form processing of casting. They can also be built using pre-cast concrete elements.

In rectangular tanks the walls are subjected to bending moments both in horizontal as well in vertical direction. The analysis of moment in the wall is difficult since water pressure results in a triangular load on them. The bending moment on the walls of tank will depend upon the several factors such as length, breadth and height of tank, and conditions of the support of the wall at the top and bottom edge. If the length of the wall is more in compression to its height the moment will be mainly in vertical direction i.e. the panel will bend as a cantilever. However, if height of the tank is larger in comparison to its length, then moments will occur in horizontal direction, and also the panel will bend as a thin slab supported on the edges. For intermediate condition bending will take place both in horizontal as well as in vertical direction. Along with the moments, the walls of the tank are also subjected to direct pull exerted by water pressure on some of the portion of side walls. The wall of the tank will thus be subjected to both bending moment as well as direct tension.

II. Problem Formulation & Analysis

The object of the present work is to compare the seismic behaviour of elevated square and circular RCC water tanks having different capacities of storage. For this purpose square and circular elevated water tanks of capacities 1 lakhs and 2 lakhs are considered to analyse under seismic forces. Heights of staging considered are 12m, 18m and 24m for square and circular tanks for both the capacities. All the models are analysed for zone III, zone IV and zone V using Staad.Pro v8i software. To study the seismic behavior of both the tanks the response parameters selected are lateral displacement and base shear.

Structural details of all the models are as follows:

Size of square water tank of capacity 1 lakhs is 6.5m x 6.5m x 2.5m.

Size of circular water tank of capacity 1 lakhs is radius 6m and depth 4m.

Size of square water tank of capacity 2 lakhs is 8m x 8m x 3.5m.

Size of circular water tank of capacity 2 lakhs is radius 8m and depth 4.5m.

Thickness of wall is 200mm.
Size of columns is 400mm x 400mm.
Size of beam at bottom of the tank is 400mm x 600mm.
Size of tie beams is 300mm x 500mm at interval of 3m.
Grade of concrete is M-30.
Grade of steel is Fe-500.

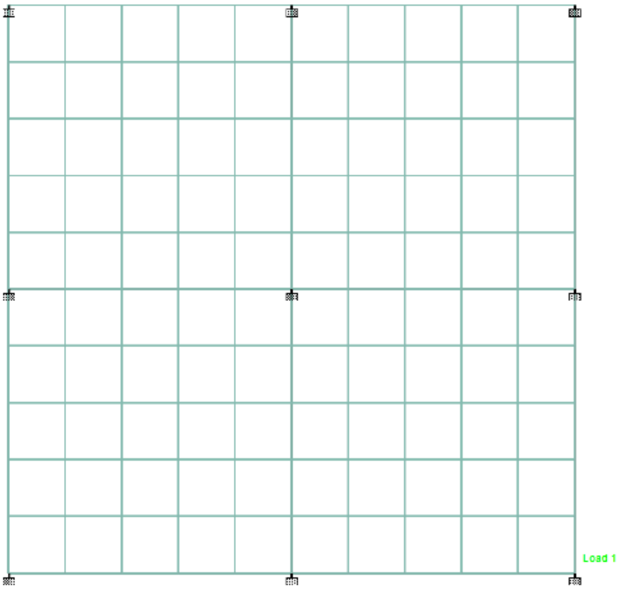

Fig. 2 Plan of square water tank

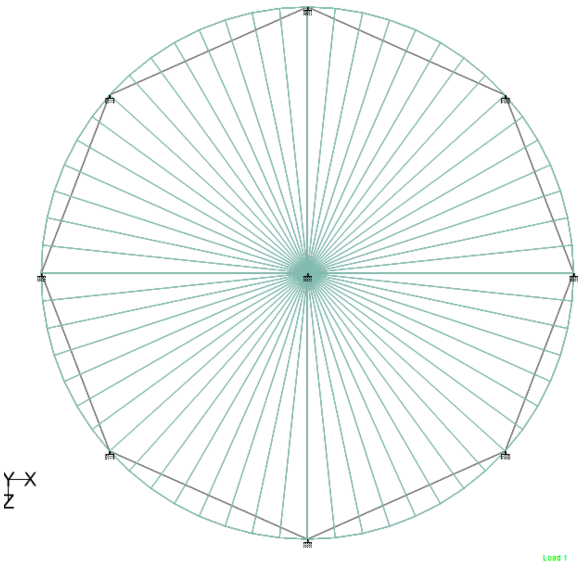

Fig. 3 Plan of circular water tank

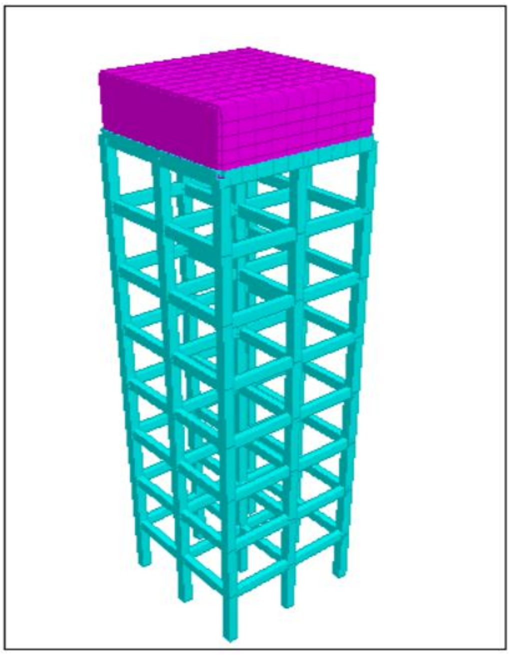

Fig. 4 Square water tank

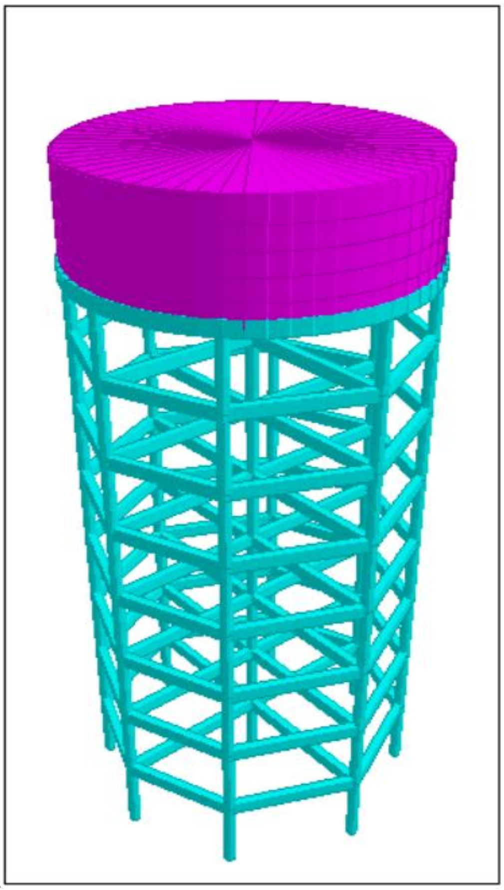

Fig. 5 Circular water tank

III. Results And Discussions

The study examines the performance of square and circular water tanks having different staging heights and storage capacities for seismic forces in zone III, zone IV and zone V. The results obtained from analysis are analysed and presented in tabular and graphical form.

To study the effectiveness of all these models, the deflection and base shear are worked out and are presented in table nos. 5.1 to 5.24 and figure nos. 5.1 to 5.24. The results organized in various tables and figures are discussed in detail.

A. EFFECT OF EARTHQUAKE ZONES ON DEFLECTION

The result shows the effect of earthquake zones on deflection by considering different staging heights for particular zone. From the results it is observed that by varying zone, the value of deflection successively increases from zone III to zone V.

B. ZONE III

For 1 lakh litre capacity in square tank for staging height 12m the value of deflection varies from 4.3mm to 21.3mm, for staging height 18m it varies from 4.1mm to 33.8mm and for staging height 24m value of deflection varies from 4mm to 48.3mm. In circular tank for staging height 12m the value of deflection varies from 5.8mm to 27mm, for staging height 18m it varies from 5.2mm to 39mm and for staging height 24m value of deflection varies from 5mm to 51mm.

For 2 lakh litre capacity in square tank for staging height 12m the value of deflection varies from 8.7mm to 43.7mm, for staging height 18m it varies from 8.26mm to 68.2mm and for staging height 24m value of deflection varies from 8.4mm to 95mm. In circular tank for staging height 12m the value of deflection varies from 9mm to 42.6mm, for staging height 18m it varies from 8.3mm to 61.5mm and for staging height 24m value of deflection varies from 7.8mm to 80.2mm.

C. ZONE IV

For 1 lakh litre capacity in square tank for staging height 12m the value of deflection varies from 5.5mm to 27.3mm, for staging height 18m it varies from 5.3mm to 42.8mm and for staging height 24m value of deflection varies from 5.1mm to 61mm. In circular tank for staging height 12m the value of deflection varies from 8.7mm to 40mm, for staging height 18m it varies from 7.9mm to 58mm and for staging height 24m value of deflection varies from 7.4mm to 76mm.

For 2 lakh litre capacity in square tank for staging height 12m the value of deflection varies from 10.7mm to 53.7mm, for staging height 18m it varies from 10mm to 82.7mm and for staging height 24m value of deflection varies from 9.7mm to 114mm. In circular tank for staging height 12m the value of deflection varies from 13.5mm to 64mm, for staging height 18m it varies from 12.4mm to 92.3mm and for staging height 24m value of deflection varies from 11.7mm to 120.3mm.

D. ZONE V

For 1 lakh litre capacity in square tank for staging height 12m the value of deflection varies from 7.4mm to 36.4mm, for staging height 18m it varies from 6.9mm to 56.4mm and for staging height 24m value of deflection varies from 6.8mm to 80mm. In circular tank for staging height 12m the value of deflection varies from 13mm to 61mm, for staging height 18m it varies from 11.8mm to 86.8mm and for staging height 24m value of deflection varies from 11.1mm to 114mm.

For 2 lakh litre capacity in square tank for staging height 12m the value of deflection varies from 13.7mm to 68.3mm, for staging height 18m it varies from 12.7mm to 104mm and for staging height 24m value of deflection varies from 12mm to 142.5mm. In circular tank for staging height 12m the value of deflection varies from 20.3mm to 95.8mm, for staging height 18m it varies from 18.5mm to 138.4mm and for staging height 24m value of deflection varies from 17.6mm to 180.5mm.

E. EFFECT OF CAPACITY AND STAGING HEIGHT ON DEFLECTION:

In the analysis staging height considered for both in square and circular water tank in all the zones is 12m, 18m and 24m. From the results it is observed that by varying staging height the value of deflection slightly decreases at height 3m, 6m and 9m. But above this height values are increasing with increase in staging height.
Similarly, from capacity point of view it is observed from the results that with increase in capacity, value of deflection also increases. In the present work capacity of tank considered is 1 lakh litre and 2 lakhs litre. The values of deflection in 2 lakhs litre is increasing largely to that of 1 lakh litre capacity and its value is observed almost double than value of 1 lakh litr capacity.

F. EFFECT OF EARTHQUAKE ZONES, CAPACITY AND STAGING HEIGHT ON BASE SHEAR

The result shows the effect of earthquake zones on base shear by considering different staging heights for particular zone. From the results it is observed that by varying zone, the value of base shear increases largely from zone III to zone V.
For 1 lakh litre capacity the value of base shear for staging height 12m in square tank is increasing from 274 KN to 615 KN from zone III to zone V, whereas in circular tank it increases from 370 KN to 833 KN. For staging height 18m in square tank is increasing from 247 KN to 556 KN from zone III to zone V, whereas in circular tank it increases from 334 KN to 751 KN. Similarly for staging height 24m in square tank is increasing from 233.5 KN to 525 KN from zone III to zone V, whereas in circular tank it increases from 313.5 KN to 705.5 KN.

For 2 lakh litre capacity the value of base shear for staging height 12m in square tank is increasing from 423 KN to 952 KN from zone III to zone V, whereas in circular tank it increases from 625 KN to 1407 KN. For staging height 18m in square tank is increasing from 371 KN to 834 KN from zone III to zone V, whereas in circular tank it increases from 570 KN to 1281 KN. Similarly for staging height 24m in square tank is increasing from 341 KN to 767 KN from zone III to zone V, whereas in circular tank it increases from 539 KN to 1212 KN.

In the analysis staging height considered for both in square and circular water tank in all the zones is 12m, 18m and 24m. From the results it is observed that by increasing staging height the value of base shear decreases for both square and circular tanks for all the earthquake zones.
Similarly, from capacity point of view it is observed from the results that with increase in capacity, value of base shear also increases. In the present work capacity of tank considered is 1 lakh litre and 2 lakhs litre. The values of base shear in 2 lakhs litre is increasing largely to that of 1 lakh litre capacity and its value is observed almost double than value of 1 lakh litr capacity.

IV. CONCLUSIONS

Within the scope of present work following conclusions are drawn:

1. For all the zones considered in both square and circular water tank deflection values follow around similar gradually increasing straight path along staging heights.
2. For all the models deflection values and base shear are less for lower zones and it goes on increases for higher zones.
3. It is experienced in all the models for all zones that values of deflection and base shear are increasing largely almost double as the capacity increases from 1 lakh litre to 2 lakhs litre.
4. From staging point of view it is observed that as the height increases from 12m to 18m and 24m, deflection slightly decreases at 3m, 6m and 9m but above that it increases.
5. By increasing staging height the value of base shear decreases for both square and circular tanks for all the earthquake zones.
6. In comparison to square and circular water tanks value of deflection and base shear are observed more in circular tank and less in square tank.

REFERENCES

[1] 2008, A. Dogangun 1, and R. Livaoglu, "*A Comparative Study of The Seismic Analysis of Rectangular Tanks According To Different Codes*".

[2] 2010, Malhotra, Praveen, Wenk, Thomas, Wieland, Martin, "*Simple procedure for seismic analysis of liquid-storage tanks*".

[3] 2011, Konstantin Meskouris, Britta Holtschoppen, Christoph Butenweg, Julia Rosin, "*Seismic Analysis of Liquid Storage Tanks*".

[4] 2012, Ayazhussain M. Jabar1, H. S. Patel, "*Seismic Behaviour of RC Elevated Water Tank Under Different Staging Pattern And Earthquake Characteristics*".

[5] 2013, L. Kalani Sarokolayi, B. Navayi Neya, J. Vaseghi Amiri and H. R. Tavakoli, "*Seismic Analysis of Elevated Water Storage Tanks Subjected to Six Correlated Ground Motion Components*".

[6] 2013, Syed Saif Uddin, "*Seismic Analysis of Liquid Storage Tanks*".

[7] 2014, S. K. Jangave, Dr. P. B. Murnal, "*Structural Assessment of Circular Overhead Water Tank Based on Frame Staging Subjected to Seismic Loading*".

[8] 2015, Jay Lakhanakiya, Prof. Hemal J. Shah, "*A Parametric Study of an Intze Tank Supported On Different Stagings*".

[9] 2015, Pradnya V. Sambary, D.M. Joshi, "*Seismic Analysis of RC Elevated Water Tanks*".

[10] 2015, Rupachandra J. Aware, Dr. Vageesha S. Mathada, "*Seismic Analysis of Cylindrical Liquid Storage Tank*".

[11] 2016, Ankush N. Asati, Dr.Mahendra S.Kadu, Dr. S. R. Asati, "*Seismic Analysis and Optimization of RC Elevated Water Tank Using Various Staging Patterns*".

[12] 2016, Sivy Martin, Musil Milos, "*Seismic Resistance of Storage Tanks Containing Liquid in Accordance With Principles of EUROCODE 8 Standard*".

[13] 2017, A. C. Chougule, P. A. Chougule, S. A. Patil, "*Study of Seismic Analysis of Water Tank at Ground Level*".

[14] 2017, Mayank Gopal Manwani1, Deepa P. Telang, "*Review on Seismic Analysis of Elevated Water Tank with Variations of H/D Ratio and Container Shape*".

[15] 2017, Nimmy Sen Sebastian, Dr.Abey.E.Thomas, Jency Sara Kurian, "*Seismic Analysis of Elevated Water Tank In A Framed Building*".

[16] IS 456-2000 *Code for plain and reinforced concrete*.

[17] IS 3370-1965 *Code for concrete structures for the storage of liquids.*