Volume 2, Issue 12, December-2015, pp. 965-970 ISSN (O): 2349-7084

International Journal of Computer Engineering In Research Trends

Available online at: www.ijcert.org

Structural assessment for reinforced concrete elevated overhead water tank

[1]SK.NASEEMA , [2]G.SHANI PRIYANKA

[1](M.Tech) Structural Engineering, Dept. of Civil Engineering
[2]Associate Professor, Dept. of Civil Engineering
Priyadarshini Institute of Technology & Management

Abstract:- Storage reservoirs and overhead tank are used to store water, liquid petroleum, petroleum products and similar liquids. The force analysis of the reservoirs or tanks is about the same irrespective of the chemical nature of the product. As from very offensive past records, many reinforced concrete elevated water tanks were collapsed or highly damaged during the earthquakes all over the world. General observations are pointing out the reasons towards the failure of supporting system which reveals that the supporting system of the elevated tanks has more critical importance than the other structural types of tanks. Most of the damages observed during the seismic events arise due to the causes like improper/unsuitable design of supporting system, mistakes during selection of supporting system, improper arrangement of supporting elements and/or underestimated demand or overestimated strength. The present work aims at checking the adequacy of water tank supported on shafts for the seismic excitations. The result shows that structure response is exceedingly influenced by different capacities of water tank and their one mass and two mass models and earthquake characteristics.

Keywords – Elevated water tanks, Reinforced concrete, Seismic response, Tank Staging.

1. INTRODUCTION

A water tank is used to store water to tide over the daily requirement. In the construction of concrete structure for the storage of water and other liquids the imperviousness of concrete is most essential .The permeability of any uniform and thoroughly compacted concrete of given mix proportions is mainly dependent on water cement ratio .The increase in water cement ratio results in increase in the permeability .The decrease in water cement ratio will therefore be desirable to decrease the permeability, but very much reduced water cement ratio may cause compaction difficulties and prove to be harmful also. Design of liquid retaining structure has to be based on the avoidance of cracking in the concrete having regard to its tensile strength. During the past earthquakes, tanks have suffered with varying degree of damages, which include: Buckling of ground supported slender tanks (Malhotra, 1997), rupture of steel tank shell at the location of joints with pipes, collapse of supporting tower of elevated tanks[1] (Manos and clough, 1983, Rai, 2002), cracks in the ground supported RC tanks, etc. Water tanks can experience distress in different components due to several reasons such as improper structural configuration design, inferior materials and workmanship, corrosion of reinforcement, wind forces, earthquake forces etc. Because of large mass, especially when the tank is full, earthquake forces are more or less govern the lateral force design criteria in the zone of high seismic activity. In the extreme case, total collapse of tank shall be avoided.

1.1 Shaft type staging:

Shaft Staging

It is a tower in the form of shaft is called shaft staging .Staging consisting of shell like a circular or polygonal cylinder or hollow prism.The tower may be in the form of single shaft circular or polygonal in plan and may be tapering. The area enclosed within the shafts may be used for providing the pipes, stairs, electrical control panels, valves, etc. The shaft staging is to be designed for vertical load[2] due to the weight of the container, the weight of the water and the self weight as well as horizontal forces due to wind or earthquakes.

Types of shaft staging

1. Polygonal Shaft
2. Circular shaft

Failure of Shaft staging

Hollow circular shaft is the most popular type of staging to support a tank container. The height of the shaft varied from a minimum of about 10m to a maximum of 20m whereas the shape and size of the tank container largely depended on the storage capacity and required head for the water supply. The affected tanks varied in their storage capacity from 80 kL to 1000 kL. The diameter of the staging generally increases with increase in the capacity of the tank, however, the thickness of the staging section is usually kept between 150 and 200 mm. The flexure cracks in staging were observed from the level of the first lift to several lifts reaching one-third the height of the staging. These cracks are mostly in a circumferential direction and cover the entire perimeter of the shaft. They usually appear near the edges of the form used during casting of the shaft, which appear to form planes of weaknesses along the shaft's length. These cracks pass through the thin section of the staging and are clearly visible from inside too

The elevated water tanks are inverted pendulum-type structures which resist lateral forces by the flexural strength and stiffness of their circular hollow shaft type staging. The section close to the ground is subjected to the maximum flexural demand. Any damage to the staging at this critical section should be considered alarming as it can seriously undermine its lateral load-carrying capacity. However, most of these tanks are being used as before. In a few cases, for example, the water tank in Darbar Garh, Morbi was repaired by injecting epoxies in the cracks. The observed damage pattern is consistent with the expected response of these structures under lateral loads. While many water tanks escaped the earthquake with minor to severe flexural crack..The Gulaotal water tank was more seriously affected because it was nearly full when the earthquake struck, whereas the other one was only 60% full. The Gulaotal tank developed flexural-tension cracks along half its perimeter, on diametrically opposite sides. The section close to the ground is subjected to the maximum flexural demand for a uniform. Any damage to the shaft at this critical section should be considered serious as it can significantly undermine its lateral load carrying capacity[3]. In fact, the water tank was taken out of the city water distribution system, causing severe hardship to neighboring residents particularly in the summer months. The observed damage pattern is consistent with the expected response of these structures under lateral loads.

2. JOINTS IN LIQUID RETAINING STRUCTURES

2.1 MOVEMENT JOINTS

(i) Contraction Joint.

It is a movement joint with deliberate discontinuity without initial gap between the concrete on either side of the joint. The purpose of this joint is to accommodate contraction of the concrete. A contraction joint may be either complete contraction joint or partial contraction joint. A complete contraction joint is one in which both steel and concrete are interrupted and a partial contraction joint is one in which only the concrete is interrupted, the reinforcing[4] steel running.

(ii) Expansion Joint.

It is a joint with complete discontinuity in both reinforcing steel and concrete and it is to accommodate either expansion or contraction of the structure.

(iii) Sliding Joint.

It is a joint with complete discontinuity in both reinforcement and concrete and with special provision to facilitate movement in plane of the joint

3. REVIEW OF LITERATURES

A. M. Kalani and A. Salpekar

Regarding different staging configuration, paper gives a comparative study between conventional and matrix methods of analysis for staging of overhead water tanks. Using computer program economic dimensions and design have been carried out. The geometrical dimensions of the system remains the same except that the number of columns considered as 6, 8 and 10 with inclination of column varies with 0°, 30° and 60°. Here, straight bracings are provided at three levels, which divide the staging in four panels. The stiffness of ring beam connecting top end of columns is considered doubled and bottom ends of the columns are assumed to be clamped with base. These are an approximations considered for the analysis. The maximum bending moment and axial force in columns occur in the lowest panel. The combined stresses gives 27.2% higher value in conventional method. Same way values of bending moment[6], torsion moment and shear forces in braces are also higher by 62.1%, 2.7% and 54% respectively. A number of parametric studies, such as the effect in stresses, loading and design of number of braces, column and also the batter of columns, have been carried out and it is observed that Axial force in column is not much affected by the batter in the column while stress-resultants in braces decrease about 28.8% to 27.6% and horizontal displacement at various braces level decrease about 28% to 37% with increase in the batter of the column.

B. R. K. Ingle

In this paper overhead water tank structure is designed using P-DELTA effect. As per IS: 456 the final design forces shall include the effect of deformation[5] (P-DELTA effect), and it is silent about the calculating this additional forces. As per IS:11682 evaluate the effective length of column and calculate these forces due to its slenderness ratio. According to the ATC code consideration of PDELTA effect is necessary if the stability index is more than 0.1 which depend upon drift ratio, story height, vertical and horizontal forces. For the study different shape of the column and its arrangement that is tangentially or radially are considered. And these arrangements plays important role in reducing drift and the stability index.

C. S. C. Dutta, et al.

Elevated water tanks have failed during past earthquakes including 1952 kern county and recent 1993 killari earthquakes owing to large torsional response. So these earthquakes have highlighted the importance of this problem. It is established that these structures may have amplified torsional-induced rotation if their torsional to lateral natural period ratio is close to 1 and also displacement of structural elements due to the coupled lateral- torsional vibration if J is within the range 0.7 to 1.25. The aim of this paper is assessing their torsional vulnerability. In 1993 killari[7], India earthquake one RC elevated water tank collapsed vertically downwards, burying the six supporting columns directly underneath the bottom slab of its container due to torsional vibration. Elevated water tanks, with their broadly axisymmetric geometry and mass distribution, should have no considerable eccentricity between centre of mass and centre of stiffness

D. R. Livaoglu and A. Dogangun

Here attempt is made to find out the effects of supporting systems on the seismic response of elevated tanks considering the fluid-structure interactions. Finite elements in the frame type support system are modeled as frame elements and truncated cone and container walls are modeled with shell elements. Also shaft supporting system is modeled shell elements. In order to characterize fluid-elevated model (FEM) considered for the elevated tank-fluid system in this study. Columns and beams tank model and to determine the seismic behavior of the system, transient dynamic analysis was carried out using the FEM analysis program. In the seismic[8] analysis, it is assumed that tanks are subjected to North-South component of the ground motion recorded at the Turkey. The time history analyses were carried out by using Rayleigh damping[9].

4. MODAL PROVISION

One mass model

Elevated tanks shall be regarded as systems with a single degree of freedom with their mass concentrated at their centre of gravity. The analysis shall be worked out both when the tank is full and when empty.

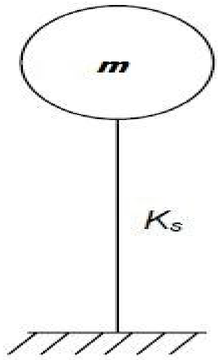

Fig.1: One mass idealization of tank

Structural mass m, includes mass of container and one-third mass of staging. Mass of container comprises of mass of roof slab, container wall, gallery, floor slab, and floor beams. When full, the weight of contents is to be added to the weight under empty condition. Staging[10] acts like a lateral spring and one-third mass of staging is considered. The free period T, in seconds, of such structures shall be calculated from the following formula:

$$T = 2\pi\sqrt{\frac{\Delta}{g}}$$

Δ – is deflection of center of gravity of tank when a lateral force of magnitude equal to W is applied at the center of gravity of tank.
g – acceleration due to gravity.
For modeling of the one mass model the lateral stiffness Ks is calculated by applying the lateral force to the staging of the existing tank. And deflection (Δ) is noted then by using following formula the stiffness is calculated.
K = P / Δ ………..(1)
This calculated stiffness is given by ,
K = 3EI / L3………(2)
Where, EI – flexural rigidity of structure.
Equating eqn (1) and (2) ; The equivalent diameter (De) for one mass model is calculated.

Two mass model

A satisfactory spring mass analogue to characterize basic dynamics for two mass model of elevated tank was proposed by Housner (1963) after the chileane earthquake of 1960, which is more appropriate and is being commonly used in most of the international codes including GSDMA[11] guideline. The pressure generated within the fluid due to the dynamic motion of the tank can be separated into impulsive and convective parts.
When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration[15]. The liquid in the lower region of tank behaves like a mass that is rigidly connected to tank wall, termed as impulsive liquid mass. Liquid mass in the upper region of tank undergoes sloshing motion, termed as convective liquid mass. For representing these two masses and in order to include the effect of their hydrodynamic[14] pressure in analysis, two-mass model is adopted for elevated tanks. In spring mass model convective mass (mc) is attached to the tank wall by the spring having stiffness (Kc), whereas impulsive mass (mi) is rigidly attached to tank wall. For elevated tanks two-mass model is considered, which consists of two degrees of freedom system. Spring mass model can also be applied on elevated tanks, but two-mass model idealization is closer to reality.

The two-mass model was first proposed by G. M. Housner (1963) and is being commonly used in most of the international codes. The response of the two-degree of freedom system can be obtained by elementary structural dynamics. However, for most of elevated tanks it is observed that both the time periods are well separated. Hence, the two-mass idealization can be treated as two uncoupled single degree of freedom system as shown in Fig. 2 (b). The stiffness (Ks) is lateral stiffness[12] of staging. The mass (ms) is the structural mass and shall comprise of mass of tank container and one-third mass of staging as staging will acts like a lateral spring. Mass of container comprises of roof slab, container wall, gallery if any, floor slab, floor beams, ring beam, circular girder, and domes if provided. The two- mass model is shown in Fig. 2.

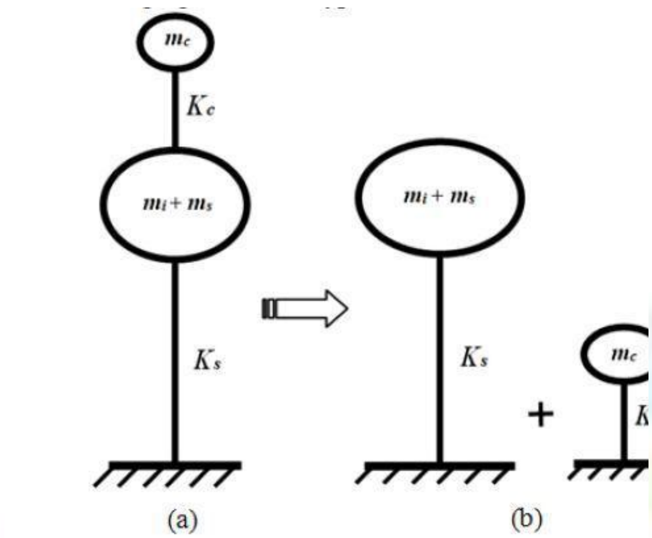

Fig.2: Two mass model for elevated tank

Where, mi, mc, Kc, etc. are the parameters of spring mass model and charts as well as empirical formulae are given for finding their values. The parameters of this model depend on geometry of the tank and its flexibility. Lateral stiffness of the staging is the horizontal force[13] required to be applied at the center of gravity of the tank to cause a corresponding unit horizontal displacement.

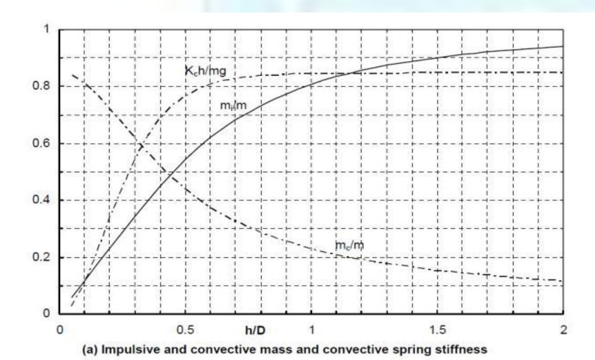

Fig.3: impulsive and convective mass and convective spring stiffness

Time period of impulsive mode, Ti in seconds, is given by;

$$T_i = 2\pi\sqrt{\frac{m_i + m_s}{K_s}}$$

Where
mi = impulsive mass
mc = mass of container and one-third mass of staging, and
Ks = lateral stiffness of staging.

5. CONCLUSION

Generally, when earthquake occur major failures of elevated water tank take place due to failure of supporting systems, as they are to take care for seismic forces. Therefore supporting structures of elevated water tanks are extremely vulnerable under lateral forces due to an earthquake. Looking to the above literature study only frame type staging with a single row of columns placed along the periphery of a circle, are not adequate to support container of elevated water tanks. Apart from that, it is required to identify suitable modified water tank staging system by determining what improvements or added features are necessary for staging part of water tank for better performance during earthquake. Also, alternate or innovative configurations are also required to put in practice. A reviewed literature demonstrates the considerable change in seismic behavior of elevated tanks with consideration of responses like displacement, base shear, base moment, sloshing, torsional vulnerability. Finally study discloses the importance of suitable supporting configuration to remain with stands against heavy damage/failure of elevated water tanks during seismic events.

REFERENCES

[1] Chirag N. Patel, H. S. Patel‖ Supporting systems for reinforced concrete elevated water tanks‖, International Journal of Advanced Engineering Research and Studies, Vol. II, Issue I, Oct.-Dec.,2012.

[2] S.K. Jain, U.S. Sameer, ―Seismic Design of Frame Staging for Elevated Water Tanks‖, Ninth Symposium on Earthquake Engineering, Roorkee, December 14-16, 1990, Vol.1.

[3] G. W. Housner, The Dynamic Behavior of Water Tanks, Bulletin of the Seismological Society of America, Vol.53, No.2, pp.381-387, Feb1963.

[4] Durgesh C Rai, (2003) ―Performance of Elevated Tanks in Mw 7.7 Bhuj Earthquake of January 26th,

2001‖ International journal of advanced engineering research Proc. Indian Acad. Sci. (Earth Planet. Sci.), 112, No. 3, September 2003, pp. 421-429

[5] Chirag N. Patel, Burhan k. kanjetawala, H. S. Patel ―Influence of Frame Type Tapered Staging on Displacement of Elevated Water Tank ‖ GIT-Journal of Engineering and Technology, ISSN 2249 – 6157, Sixth volume, 2013,

[6] Pravin B.Waghmare, Atul M. Raghatate & Niraj D.Baraiya ―Comparative Performance of Elevated Isolated Liquid Storage Tanks (With Shaft Staging)‖, International Journal of Advance technology in civil engineering, ISSN:2231-5721, Volume 1, Issue 2-2012.

[7] S. C. Duta, S. K. Jain and C. V. R. Murty, ―Assessing the seismic torsional vulnerability of elevated tanks with RC frame-type staging‖, Soil Dynamics and Earthquake Engineering (ELSEVIER), 2000, Vol. 19, pp. 183-197

[8] S. C. Duta, S. K. Jain and C. V. R. Murty, ―Alternate tank staging configurations with reduced torsional vulnerability‖, Soil Dynamics and Earthquake Engineering (ELSEVIER), 2000, Vol. 19, pp. 199-215

[9] IS: 11682-1985, Criteria for Design of RCC Staging For Overhead Tanks (1985),Bureau of Indian Standards, New Delhi,

[10] M. Kalani and S. A. Salpekar, ―A comparative study of different methods of analysis for staging of elevated water tanks‖, Indian Concrete Journal, July-August – 1978, Pg No.210-216.

[11] M. V. Waghmare, S.N.Madhekar ―Behaviour of elevated water tank under Sloshing effect‖ International Journal of Advanced Technology in Civil Engineering, Volume-2, Issue-1, 2013

[12] S.K.Jain & et al., ― proposed provision of aseismic design of a liquid storage tank‖ , journal of structural engineering,vol 20 no.4 january 1994 pp. 167-175.

[13] Ayazhussain.M.Jabar, H.S.Patel, ―Seismic Behaviour Of RC Elevated Water Tank Under Different Staging Pattern And Earthquake Characteristics‖, International Journal Of Advanced Engineering Research And Studies, April-June2012.

[14] Pavan .S. Ekbote, Jagdish Kori, ―Seismic Behaviour of RC Elevated Water Tank under Different Types Of staging Pattern‖, Journal Of Engineering,Computers and Applied Sciences, Volume 2, No.8, August 2013.

[15] .R. Livaoglu, A. Dogangün, ―An Investigation about Effects of Supporting Systems on Fluid-Elevated TanksInteraction‖, First International Conference on Seismology and Earthquake Engineering (SEE), Turkey, May – 2007

