



SEISMIC ANALYSIS OF WATER TANKS WITH DIFFERENT CAPACITIES: A REVIEW

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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. To understand the behavior of RCC water tanks with different capacities various literatures related to different water tanks are studied and reviewed in this paper. From the review it is concluded that due to improper geometrical selection and supporting systems various water tanks are collapsed or heavily damaged. As during post-earthquake period water supply is essential, so these special structures as water tanks should remain functional in this period.

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.



Figure 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. Literature

The construction of reinforced concrete water tanks has become widely used in many countries. Researches on the seismic behavior of the rcc water tanks are described below:

(2008), A. Dogangun, and R. Livaoglu, “A Comparative Study of The Seismic Analysis of Rectangular Tanks According to Different Codes”, carried out a comparative seismic analysis for a rectangular tank considering requirements and expressions which are provided in seismic codes for USA, European Community and New Zealand. Also, they discussed Turkish seismic code. Hydrodynamics pressures, sloshing displacements, base shears, lateral displacements, bending and overturning moments are determined for considered codes and specifications. Finally, the results obtained by this work are evaluated and some conclusions encountered differences and similarities for seismic analysis and design of rectangular tanks.

Main requirements for rectangular tank were presented in ACI 350 and Eurocode 8 Part 4. Analyses were carried out for simple rectangular tank. Lesser impulsive mass and bigger convective mass is obtained from ACI 350 as compared to those obtained for Eurocode 8. From ACI 350 for bending moment related to these masses smaller equivalent heights are obtained, but for overturning moment larger heights are obtained. The main critical result parameter to verify for engineers is impulsive period of the rectangular water tank. Eurocode 8 gives practical formulation for impulsive period for cylindrical tanks. To estimate this period lateral displacement should be determined. The hydrodynamic pressure distribution and magnitude obtained by Eurocode 8 and ACI 350 are generally in agreement. The differences between hydrodynamic pressures were occurred top and bottom of the tank wall.

(2010), Malhotra, Praveen, Wenk, Thomas, Wieland, Martin, “Simple procedure for seismic analysis of liquid-storage tanks”, provided the theoretical background of a simplified seismic design procedure for cylindrical ground-supported tanks. In flexible steel or concrete tanks fixed to rigid foundations this procedure considers impulsive and convective (sloshing) actions of the liquid. Result parameters as base shear, overturning moment, and sloshing wave height are calculated by using the site response spectra and performing a few simple calculations. An example is presented to illustrate the procedure, and a comparison is made with the detailed modal analysis procedure. The simplified procedure has been adopted in Eurocode 8. As per the Eurocode 8, the analysis assumed linear elastic behaviour, allowing only for localized non-linear phenomena without affecting the global response, and to include the hydrodynamic response of the fluid. Particularly, it should account for the convective and impulsive components of fluid motion as well as the tank shell deformation due to hydrodynamic pressure and interaction effects with the impulsive component. The proposed procedure satisfies these principles in a simple and efficient way for the design of fixed-base cylindrical tanks.

(2011), Konstantin Meskouris, Britta Holtschoppen, Christoph Butenweg, Julia Rosin, “Seismic Analysis of Liquid Storage Tanks”, presented the state of the art of tank design with special focus on the practicability of the available design rules. Analytical and numerical calculation approaches are compared on the example of a typical tank geometry, taken the relevant interaction effects into account. During strong earthquakes, it is significant that the structural reliability of tanks



containing liquids is maintained in order to not jeopardize the population's supply with essential goods. The continuous operation of tanks after strong earthquakes requires safe and effective design rules. The overall seismic behaviour of tanks is, however, quite complex, since the dynamic interaction effects between tank wall and liquid must be considered. The interaction can be simplified with the concept of generalized single-degree-of-systems representing the convective, rigid impulsive and flexible impulsive vibration modes of tank and liquid. This concept is well accepted for anchored tanks with a fix connection to a rigid foundation. They provided guidance for the implementation of normative demands for the seismic design of liquid filled tanks. With the tabulation of different factors the cumbersome mathematical formulas for calculating the load components are avoidable, which allows an easy load generation for finite element analysis.

(2012), Ayazhussain M. Jabar¹, H. S. Patel, “Seismic Behaviour of RC Elevated Water Tank Under Different Staging Pattern and Earthquake Characteristics”, focused to understand the behaviour of supporting system which is more effective under different earthquake time history records with SAP 2000 software. Supporting systems are compared with basic supporting system for various fluid level conditions. For later conditions water mass has been considered in two parts as impulsive and convective suggested by GSDMA guidelines. In addition to that impulsive mass of water has been added to the container wall using Westergaard’s added mass approach. For the analysis they considered tank with capacity of 1000m³. Also they considered basic staging, radial staging and cross staging pattern. From the analysis various result parameters are observed and then the results have been compared and contrasted. As the result parameters shows that the structure responses are extremely influenced by the existence of water and the earthquake characteristics. High frequency content an earthquake record causes excitation of parameters such as base shear force, overturning moment and roof displacement are compared and following conclusions are obtained.

1. In Loma Prieta time history, higher base shear for cross bracing pattern is obtained in empty condition.
2. For Kobe earthquake, lower base shear and overturning moment in cross bracing and radial bracing pattern respectively in empty condition.
3. In Loma Prieta and Kobe earthquake, lowest base shear and overturning moment for radial bracing are obtained in case of half- full condition.
4. In half-full condition for Loma Prieta, basic staging overturning moment is highest having high PGA value.
5. In Imperial Valley, highest base shear is obtained for radial bracing having low PGA value in case of Full condition.
6. With increase in PGA value of earthquake time history roof displacement considerably decreases and also noted higher value in Imperial Valley.
7. Higher Roof displacement values are obtained in full fill up condition for all patterns.

(2013), L. Kalani Sarokolayi, B. Navayi Neyya, J. Vaseghi Amiri and H. R. Tavakoli, “Seismic Analysis of Elevated Water Storage Tanks Subjected to Six Correlated Ground Motion Components”, defined rotational components of ground motion acceleration according to improved method from the corresponding available translational components based on transversely isotropic elastic wave propagation in the soil. With such improvement, it becomes possible to consider frequency dependent wave velocities on rotational components of ground motion. Therefore, 3 translational elements of El Centro earthquake (24 January 1951) will generate their relative rotational components based on SV and SH wave incidence by Fast Fourier transform with 4096 discrete frequencies. The translational and computed rotational motions were then applied to the concrete elevated water storage tanks with different structural characteristics and water elevations. Finite element method is employed for the analysis of water storage tanks in consideration to the fluid-structure interaction using Lagrangian-Lagrangian approach and therefore the concrete material



nonlinearities are taken into consideration through William-Warke model. The nonlinear response of these structures considering the six components of ground motion showed that the rotational components of ground motion can increase or decrease the maximum displacement and reaction force of the structure. The frequency of structure and predominant frequencies of translational and rotational components of ground motion are responsible for these variations. They made the following conclusions by the analysis:

1. The increase in the base shears and vertical reaction forces of tanks due to rotational excitations of ground motion is the largest for elevated tank with short height (about 6 meter). This structure is laterally stiff and rotationally flexible and the accidental torsion could be larger than those proposed by the design codes.
2. In water tanks rotational elements can be a lot of importance with less elevation of water, as a result of which, their natural frequencies are changed close to predominant frequency of rotational components. In this study, the increase of water elevation increased the rotational stiffness of water storage tanks and decreased the response of structures.
3. Wherever, structure is rotationally versatile and laterally stiff; the rotational components of ground motion will increase the response of structure. This result is inversed for rotationally stiff structures.
4. In elevated tanks it is observed that the accidental torsion depends on the structural characteristics and torsion eccentricities of these structures need to be considered especially for tanks with short height.
5. The analyses showed structure responses are changed by change of peak acceleration, frequency content of earthquake and its rotational components, soil type, water elevation and tank characteristics. Hence, 6 component ground motion analysis of these structures are necessary for design control.

(2013), Syed Saif Uddin, “Seismic Analysis of Liquid Storage Tanks”, studied the behavior of liquid storage tanks under earthquake loads as per Draft code Part II of IS 1893:2002. Software SAP 2000 is used for seismic analysis of tanks which gives the earthquake induced forces on tank systems. Indian standard earthquake code IS 1893:1984 have some limitations on seismic design of elevated tanks. This code did not cover ground-supported tanks. Dynamic analysis of liquid containing tank is a complex problem involving fluid-structure interaction. Under earthquake loads, a complicated pattern of stresses is generated in the tanks. Due to earthquake inadequately designed tanks have leaked, buckled or even collapsed. General failures due to earthquake are wall buckling, sloshing damage to roof, inlet/outlet pipe breaks and implosion due to rapid loss of contents. This thesis consists of two different parts. The first part focuses on a theoretical point of view & formulations for analysis. The second part focuses on the model example to determine the seismic forces on tank. Significantly the results reviews earthquake induced forces on container systems and it is observed that there is a maximum increase of 15% to 25% in hydrodynamic pressures in elevated tanks and ground supported tanks, respectively. An example intz shape tank is designed as per the Indian codes IS : 3370-1965/1967(parts I to IV), IS:456-2000, IS 1893 (Part 1):2002, draft code Part II of IS 1893:2002.

In the given example problem, the maximum hydrodynamic pressure is about 15% of hydrostatic pressure at base ($p_{gh} = 1000 \times 9.81 \times 4.0 = 39.24 \text{ KN/m}^2$). There is a need to specify increase in permissible stresses when earthquake forces are included in the design forces in the draft code while designing the liquid container using the working stress method.

(2014), S. K. Jangave, Dr. P. B. Murnal, “Structural Assessment of Circular Overhead Water Tank Based on Frame Staging Subjected to Seismic Loading”, aimed to understand the seismic behaviour of the elevated water tank with consideration and modeling of impulsive and convective water masses inside the container as one mass model and two mass model as per IS:1893-2002 under



different time history records using finite element software SAP 2000. The present work aims at checking the adequacy of water tank for the seismic excitations. It is determined from the results that response of structure is extremely influenced by completely different capacities of water storage tank and their one mass and two mass models and earthquake characteristics. The responses include displacement at top level and base shear of existing model and its one mass and two mass model under the four different time history have been compared. The obtained results are summarized as follows:

1. The critical response depends on the earthquake characteristics and particularly frequency content of earthquake records.
2. It is observed that the displacements for two mass models are less than one mass and existing model. Base shear also shows a minimum value for two mass model for all the three capacities.
3. As per comparison the values of displacements and base shear are In order: One Existing Two.
4. The responses i.e. displacement and base shear are nearly same for one mass model and two mass model.
5. In some cases, existing model shows maximum displacement than one mass than two mass model.
6. There is sudden change in displacement values for north ridge earthquake data. All the above modeled water tanks show maximum displacement for north-ridge earthquake data and minimum displacement for koyana earthquake data for all tank capacities.

(2015), Jay Lakhanakiya, Prof. Hemal J. Shah, “A Parametric Study of an Intze Tank Supported on Different Stagings”, focused on hydrodynamic analysis of Intze water tank and comparison of the cost of water tank for different staging conditions like shaft and frame type. To achieve the work, they designed container of the water tank by using excel worksheet. And in this excel worksheet hydrodynamic analysis is carried out. The staging part is analyzed in software STAAD Pro. V8i and the design has been done in excel worksheet. Tanks considered for analysis were same in dimensions and capacities for all the different staging. For frame type supporting system the horizontal parallel type bracing was considered at various levels. The types of staging considered in this study are frame type and shaft. The recommended dimension for container remains same for same capacities. Various capacities considered are 10 lacs, 15 lacs, 20 lacs, 25 lacs litters. Numbers of column considered in study are 8, 12, and 14. Height of staging considered is 15 m and 18 m. The spacing of bracing is 3m and 5m or 6m. The column is arranged in outer periphery. Parallel type of bracing is considered for all the models. Earthquake Zones considered is III, IV, V. Soil type soft, medium and hard considered. Here various parameters change is tank capacity, number of columns, height of staging, spacing of bracing, earthquake zone and soil type. The estimating and costing of water tank is done using GWSSB- SOR (2013-14). Following conclusions are drawn from the analysis:

1. Cost of water tank on frame type staging is more than shaft type staging.
2. Cost of water tank is increase with increase in number of columns from 8 to 12 and 12 to 14.
3. For 18 m height of staging bracing spacing of 6 m is economical than bracing spacing of 3 m.
4. For 15 m height of staging bracing spacing of 5 m is economical than bracing spacing of 3 m.
5. Cost of water tank is increase with change in Zone 3 to Zone 5.
6. Cost of water tank is increase with change in soil type hard soil to soft soil.
7. Base shear and overturning moment increase with decrease in bracing spacing.
8. The increment in base shear and overturning moment is very large with change in Zone 3 to Zone 5.
9. The increment in base shear and overturning moment is very large with change in hard soil to soft soil.
10. The increment of cost from zone 3 to zone 4 is average 11 % and from zone 3 to zone 5 is 31% for the hard soil.



11. The increment of cost from zone 3 to zone 4 is average 18 % and from zone 3 to zone 5 is 54% for the medium soil.
12. The increment of cost from zone 3 to zone 4 is average 22 % and from zone 3 to zone 5 is 85% for the soft soil.
13. The increment of cost from hard soil to medium soil is average 6 % and from hard soil to soft soil is 15% for zone 3.
14. The increment of cost from hard soil to medium soil is average 13 % and from hard soil to soft soil is 27% for zone 4.
15. The increment of cost from hard soil to medium soil is average 25 % and from hard soil to soft soil is 62% for zone 5.

(2015), Pradnya V. Sambary, D.M. Joshi, “Seismic Analysis of RC Elevated Water Tanks”, carried out manual seismic analysis of elevated circular water tank in accordance with IS: 1893-1984 (i.e. lumped mass model) and IS: 1893-2002 (Part-2) draft code (i.e. two mass model). The tank is located in zones III and V and on two different soil types i.e. hard rock and soft soil. Hence there are total four cases. Further comparison between the framed type and shaft type staging is done as per manually calculated responses such as base shear and base moment. The water tanks are been analyzed for tank full and tank empty conditions for which response spectrum method is used. Seismic responses such as base shear, base moment and hydrodynamic pressure are evaluated and compared. From the analysis it is observed that the current practice gives the response of elevated tanks with reasonable accuracy. From the analysis following conclusions are made:

1. According to IS: 1893-1984 the tank as single degree of freedom system (lumped mass model) which is applicable to closed tanks completely full of water. Hence for tanks with free water surface, two mass idealization of tank are used which is incorporated in IS: 1893-2002 Draft code (Part 2).
2. IS: 1893-2002 (Part 2) has considered the sloshing motion of water surface. Due to effect of sloshing, convective pressure acts on the tank which were not given due consideration in the analysis of tank using lumped mass model concept of IS: 1893-1984.
3. With the consideration of convective hydrodynamic pressures, bases shear and base moment's values increase considerably which were quite small for lumped mass idealization of tank. Hence the bases shear and base moment values obtained from two mass idealization i.e. as per IS: 1893-2002 (Part 2) are more realistic. Hence convective pressures play a major role in seismic analysis of the elevated water tank.
4. The responses of base shear and base moment obtained from two mass idealization are far greater than that in lumped mass model. Hence idealization of water tank as single degree of freedom system is not appropriate for seismic analysis of water tanks. Hence two mass idealization should be used for dynamic analysis of water tanks.
5. The base shears, base moments and hydrodynamic pressures increase with increasing zone factors.
6. The hydrodynamic pressures calculated using IS: 1893-1984 codal provisions are by considering the rigidity of the tank wall whereas those calculated using IS: 1893-2002 (Part 2) codal provisions are by considering the flexibility of the tank wall. In consideration to flexibility of wall he impulsive pressures are very large as compared to those obtained by lumped mass model. The impulsive hydrodynamic pressures obtained by two mass model concept are almost sixteen times more than that obtained using two mass model concept. Hence lumped mass model underestimates the impulsive pressure values.
7. From the graphs, it is clear that shaft type stagings should be avoided as far as possible in the near future to avoid damage to the water tanks and thus prevent loss of lives.



(2015), Rupachandra J. Aware, Dr. Vageesha S. Mathada, “Seismic Analysis of Cylindrical Liquid Storage Tank”, studied the behaviour of cylindrical liquid storage tanks under earthquake loads as per Draft code Part II of IS 1893:2002. A FEM based computer software (STAAD -PRO) used for seismic analysis of tanks which gives the earthquake induced forces on tank systems. Under earthquake loads, a complicated pattern of stresses is generated in the tanks. Poorly designed tanks have leaked, buckled or even collapsed during earthquakes. For this they analyzed a circular cylindrical elevated water tank, with 500 cubic meters capacity and is analyzed by using finite modeling techniques. And they had done the study of seismic performance of the elevated water tanks for various heights and various seismic zones of India. The effect of height of water tank, earthquake zones on earthquake forces have been presented in this study with the help of analysis of 20 models for same parameters. Analysis is carried out by using finite element software STAAD-PRO. From the analysis following conclusions are drawn:

1. Design of water tank is a very tedious method. Particularly design of elevated cylindrical water tank involves lots of mathematical formulae and calculation. It is also time consuming. Thus this software immediately gives a base shear value from the analysis.
2. Base Shear increases from zone II to Zone V keeping all parameters of water tank constant height also.
3. Base shear is at its peak for 10m height and again goes down from 10-25 m keeping all parameters of water tank constant zone.
4. Present study will be useful to Civil Engineers to understand the behaviour of elevated water tank for various heights and also to get the feel of effect of earthquake zones of India on earthquake forces.

(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”, studied the seismic behavioral effect of circular elevated water tank for specific capacity of tank for various staging arrangements in plan, variation in number of periphery columns and variation in number of stages in elevation. Two mass idealizations suggested by Gujarat State Disaster Management Authority are considered here. Under earthquake loads; a complicated pattern of stresses is generated in the tanks. For the purpose they have considered tank with capacity of 500m³ and staging height of 16m. The type of staging considered is normal staging, radial staging and cross staging. All the models are analyzed for 6, 8, 10 and 12 columns having diameters 520mm, 450mm, 350mm and 300mm respectively. Total 36 combinations were analyzed with SAP2000 using Response Spectrum Method (RSM) and results are presented. It is observed that increase in number of columns, does not assure the increase in the improvement of structural responses. Radial arrangement with six staging levels is found to be best for the number of columns used. Radial staging arrangement with 6 staging levels are provided to suggest number of columns with suitable diameter cost optimization. It is found that eight numbers of columns give less cost as compared to six, ten and twelve with optimized diameter of 300mm. It can be said that sometimes instead of increasing number of columns for the stiffened of structure or safety, it is better to optimize after assuring proper structural responses.

(2016), SIVY Martin, MUSIL Milos, “Seismic Resistance of Storage Tanks Containing Liquid in Accordance with Principles of EUROCODE 8 Standard”, dealt with the procedure for seismic resistance of liquid storage tanks which are in accordance with the principles of Eurocode 8 standard. They performed seismic analysis on flexible (steel) circular vertical ground-supported model of tank containing liquid (water). The objective is to observe the basic seismic characteristics, dynamic properties, distributions of hydrodynamic pressure, and response of investigated tank-liquid system subjected to earthquake excitation (El Centro). Seismic analysis and results comparison are carried out on mechanical spring mass model (Eurocode 8) and finite element model (ANSYS).



Finite element model was used for comparison of dynamic properties of investigated system and for computation of the response to seismic loading using appropriate method. The results between each solution represented good conformity. Seismic analysis is one of the analyses which should be carried out to provide satisfactory performance of tanks, especially in earthquake prone regions.

Because of the various responses, rigid and flexible tanks are suitably distinguished. This difference is critical particularly when investigating the hydrodynamic pressure and tank oscillation. On the other hand, response of the convective liquid mass and its contribution to hydrodynamic pressure are not affected by wall flexibility. The flexible component of the hydrodynamic pressure has a tendency to shift a peak ordinate from the base to the top.

(2017), A. C. Chougule, P. A. Chougule, S. A. Patil, “Study of Seismic Analysis of Water Tank at Ground Level”, considered a parametric study on spring mass model, Time period in impulsive and convective mode, Design seismic horizontal element, hydrodynamic pressure and base shear due to impulsive and convective mass of water. The seismic analysis of the ground supported water tank resting on soft soil consisting of mass of roof, mass of tank wall, mass of water and mass of base slab is carried out. It has been found that under influence of seismic forces with increasing ratio of maximum depth of water to the diameter of tank (h/D) the more mass of water will excite in impulsive mode while decreasing ratio of (h/D) more the mass of water will excite in convective mode. The Time period of Impulsive mode increase with increase in (h/D) ratio and Time period in convective mode decrease with increase in (h/D) ratio. It is assumed that tank is located in seismic zone IV. For circular water tank with same storage capacity and different height; the Base shear, Bending Moment & Max. Hydrodynamic pressure gradually increases with increase in h/D ratio. In case of rectangular water tank with same storage capacity and different height of tank wall if the h/L ratio is up to 0.6 the base shear, Bending Moment & Max. Hydrodynamic pressure increases gradually and if the h/L ratio is in between 0.6 to 0.8; it suddenly increases & after that it decreases gradually. So, for water tank at ground level the h/L ratio up to 0.6 is feasible. It is observed from the results that for both the circular & rectangular water tank having same storage capacity but different wall height of tank, sloshing wave height increases up to certain limit & after that it decreases gradually. In case of circular water tank for h/D ratio 0.4, the mass participation factor for impulsive & convective are nearly equal. In rectangular water tank the mass participation factors are almost equal for h/L ratio 0.5.

(2017), Mayank Gopal Manwani¹, Deepa P. Telang, “Review on Seismic Analysis of Elevated Water Tank with Variations of H/D Ratio and Container Shape”, studied the seismic forces acting on an elevated circular and rectangular water tank with constant staging height. Also, they determined the seismic forces acting on the tank changing the Seismic Response Reduction Factor (R). IS: 1893-1984/2002 for seismic design and then checked the design of tanks by using the software STAAD PRO. From the analysis following conclusions are made:

1. Under seismic analysis due to zone factor, response reduction factor etc., base shear of full water tank and empty water tank are increased with seismic zone II-V.
2. Base shear in full condition tank is slightly higher than empty tank due to absence of water or hydro static pressure.
3. Displacement of full water tank and empty water tank are increased with seismic zone II-V because of zone factor, response reduction factor etc. while considering seismic analysis.
4. Maximum nodal displacement and minimum nodal displacement found at the wall of water tank when tank is full condition.
5. Under seismic analysis due to zone factor, response reduction factor etc, shear force and bending moment of full water tank and empty water tank are increased with seismic zone II-V.
6. Because of absence of water or hydro static pressure, shear force and bending moment in full condition tank is slightly higher than empty tank.



(2017), **Nimmy Sen Sebastian, Dr.Abey.E.Thomas, Jency Sara Kurian**, “Seismic Analysis of Elevated Water Tank In A Framed Building”, studied the performance of elevated water tanks in framed building subjected to dynamic loading, considering the effect of sloshing. They also provided certain design recommendations for elevated water tank in framed building to avoid negative damping and resonance. Linear static and non-linear dynamic analysis (Time history analysis) was conducted to estimate the earthquake response of the system. The seismic response of the building models with varying tank geometries are also discussed. Using this method, the study of liquid sloshing effects in tanks with rectangular and circular tank geometries is made possible. The design of the tank is not performed since it is an analytical comparison of the seismic performance in a framed building with varying number of storey. Elevated water tank is analyzed in framed building with the use of SAP 2000 software and the results are compared to obtain an economic design strategy. In fact, the study helps in making an Engineer aware on what all aspects he/she should consider while deciding on the tank shape, whether circular or rectangular whether placed at corner or near to centre position in a framed building. However one general comment could be made that-rectangular water tank placed near corner position in framed building performed better than another one. The results of this study help to predict the response of elevated tank in framed building with reasonable accuracy. Building model without water tank with varying number of storey (3, 6, 9, and 12) are developed for the study. Also developed the building models with rectangular and circular water tanks placed at position near to the centre and at corner with number of storey 3, 6, 9 and 12. By comparing building models with and without tank, percentage reduction in joint displacement has been observed. The percentage reduction in joint displacement seems to be more for 3 storey building model and increases with the increase in the number of storeys. From the analysis it is observed that the best position and shape of the water tank is obtained as rectangular tank placed at the corner position in a framed building. Generally, various factors mostly affect percentage reduction in joint displacement increases in a number of storeys of building, amount of water present in tank, shape and size of water tank and position of water tank. In non-linear dynamic analysis percentage reduction in joint displacement and joint acceleration has been obtained on by comparing building model with tank and without the tank. For 3 storey model percentage reduction in joint displacement and acceleration is observed more and also it increases with the number of storeys. Concrete rectangular tanks are built in a sealed sum less mould in the factory and most obvious negative to a circular tank is they are space intensive. As an example, if a circular tank in placed in a rectangular room it will waste a lot of space in that room as its corner does not cover. More limitation is that water circulation can only occur in a circular motion as because in round tank it has no difference in length and width. Debris remains in the centre of the tank. In circular tank, water exerts pressure equally in all directions when placed in a cylinder. More over for the circular tank has no corners and can be made water tight easily. The side walls are designed for hoop tension and bending moments. From the analysis it is observed that the best position and shape of the water tank is obtained as rectangular tank placed at the corner position in a framed building.

III. Conclusion

From the past research works it is concluded that due to improper geometrical selection and supporting systems various water tanks are collapsed or heavily damaged. As during post-earthquake period water supply is essential, so these special structures as water tanks should remain functional in this period.

It is said that earthquake itself never kills people; it is badly constructed structures that kill. Hence it is important to analyze the structures properly for earthquake effects.

From the past research works it is observed that so many researches are performed on the various patterns of staging of water tanks but not much work has been done on the water tank container itself.



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