A Review Study on Dynamic Response of Intze Type Elevated Water Tank using Baffle Wall

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Abstract- *Water tanks are considered a paramount element during & after an earthquake. Elevated water tanks are used to hold the water at a certain height which creates a potential difference, and hence allows the stored water to be supplied to the distribution system. According to seismic code IS1893(Part 1):2016 more than 56% of the country India comes under earthquake-prone areas. Recent earthquakes have shown that liquid storage elevated tanks are found to be susceptible to damage. This paper enlights the effect of providing cylindrical baffle walls with and without openings to reduce the sloshing effect of water on the tank walls. In this study, various literatures on the effect of baffle walls on dynamic analysis of elevated water tanks are studied.*

Keywords- *Elevated water tank, dynamic analysis, earthquake, Baffle walls, SAP 2000 Software.*

1.Introduction

1.1General

Water tanks are considered as the main lifeline element during & after the earthquake. The elevated water storage tank is a huge water storage container constructed to hold water at a certain height to pressurize the water and utilizes the natural force of gravity to supply water to the distribution system. An elevated water tank behaves like an inverted pendulum which consists huge water mass at the top of a slender staging. The support can be both shaft type as well as column supported type as per the requirement of the designer. The dynamic behaviour of a liquid storage tank as a special structure is different from general structures. Tank responses including overturning moment, base shear, sloshing displacement, and tank displacement under these three pairs of earthquake records are calculated, and then the results obtained are compared and contrasted. Results show that the system responses are highly affected by the structural parameters as well as the earthquake characteristics, such as frequency content.

According to seismic code IS: 1893(Part 1):2016 more than 56% of the areas of India are earthquake-prone areas. Recent studies have shown that liquid storage tanks are found to be vulnerable to damage when subjected to earthquake. Most of the failures of water tanks during earthquakes are caused due to dynamic buckling caused by overturning moments due to liquid inertia and sloshing of liquid in the water container induced due to earthquake. Therefore, the seismic designer of the liquid storage tank needs the information and knowledge of several parameters such as hydrodynamic pressure distribution on the tank wall, direction of seismic forces, damping, time period, base shear, base moment, the effect of vertical ground acceleration, sloshing wave height and anchorage requirement. [3].

Earthquake excitation causes sloshing of water inside the liquid storage container creating additional forces on its wall & roof. Freeboard is provided to allow liquids to slosh freely inside to prevent sloshing impact on the tank roof [1]. Post-earthquake reconnaissance reports have shown that liquid sloshing is one of the major causes of serious damage in a tank during earthquake. [4]

Fig 1: - Elevated intze water tank [11]

1.2 Concept of baffle wall

Baffles are flow directing or obstructing vanes built inside the tanks for altering the flow pattern in a tank to overcome the sloshing effect. The baffles are constructed to ensure the minimum amount of water to slosh when the tank is subjected to earthquake excitation. Due to the impact and viscous forces induced by baffles the velocity magnitude is reduced. Baffle walls are made of elastic and isotropic material. It can be constructed from concrete as well as fibre materials [4]. It can be mounted on existing columns & attached to concrete walls with clip angles. [3]

Baffles can be distinguished as below:

- Solid Baffles: These baffles are used as an obstruction perpendicular to the flow to change the direction of flow.
- Perforated Baffles: These baffles are used to divide the main flow into multiple uniform current flows without changing the direction offlow.[1]

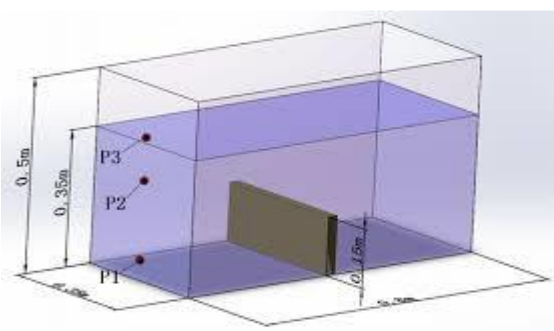

Fig 2: -Solid vertical Baffle Wall [12]

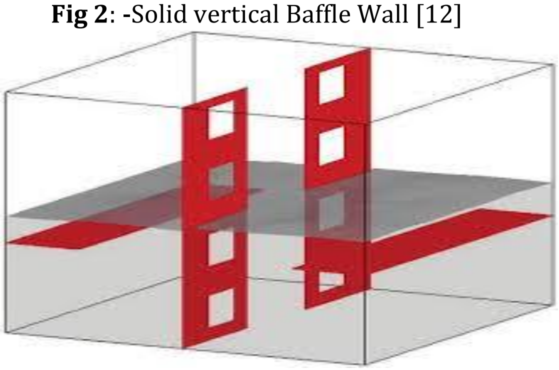

Fig 3: -Solid vertical Baffle Wall with openings [13]

2. Literature Review

Many researchers have studied the effect of baffle walls on dynamic analysis of elevated water tanks, especially in the seismic active regions. The studies of the effect of baffle walls are herein below:

Chaudhari et. al. (2017) [1], The study enlights the effect of providing baffle walls in circular water tanks to suppress the sloshing effect. They have considered two types of baffle walls i.e., Ring and vertical baffle walls. Dynamic analysis is carried out using ANSYS software. To study the effect of height of baffle wall and effect of opening patterns, three different models and models with single and multiple circular openings in baffles are prepared and analysed respectively. From all the results, the study concluded that one-half height of baffle wall has less deformation by about 32% and stresses are less by 60% to 80% than baffle wall of 1/3 or 2/3 height of the tank and baffled tank increases the performance of circular water tank when compared to the conventional tanks.

Patel & Parekh (2016) [2], The main focus was to study the seismic effect on circular and intze elevated water tanks of 10 lac litre capacities with staging heights of 12m, 16m, and 20m. Two models with shaft and frame type staging profiles are analysed at near-fault and far-field ground motion using STAAD PRO software. Seismic responses including base shear, base moment, and displacement have been observed under different earthquake time history record and concluded that base shear increases with staging height for both the profiles. Maximum variation in displacement is present in circular tank intze tank because of the absence of conical dome in circular type tank.

Mane and Kulkarni (2019) [3], In this study time history analysis of baffled rectangular and circular elevated water storage tank & analysis using SAP 2000 software has done. Comparison for parameters like base shear and maximum nodal displacement and results were compared for empty and full tank water fill conditions. Results obtained were like for baffled rectangular tank top nodal displacement decreases by 14.55% and 6.24% for empty and full condition, base shear increases by 19.36% and 19.78% for empty and full condition and baffled circular tank top nodal displacement decreases by 8.05% and 9.10% for empty and full condition, base shear increases by 13.02% and 20.88% for empty and full condition and that the time period of baffled water tanks is more than that of conventional tanks due to increase is mass of the tank.

Dhumal & Suryawanshi (2016) [4], In this study they have prepared a model of the rectangular elevated water tank with baffle wall using ANSYS software. A study on baffle walls is carried out for different parameters such as thickness, spacing of baffle walls, and effect of openings in baffle walls. In the first stage pressure and loads are calculated as per IS 1893:2002 part-2. Comparison is made between water tanks with baffle walls and without baffle wall and concluded that natural frequency and time period is increased in baffle wall tank and deformation and shear stress along the long wall is considerably reduced by using baffle walls. It is clear that baffle walls increase the performance of the water tank against hydrodynamic water pressure.

Dalvi et. al. (2017) [5], In this study the sloshing effect, i.e., action of hydrodynamic pressure on ground rested rectangular tank with single and multiple equidistant vertical baffle wall has been analysed. The base shear, hydrodynamic forces, sloshing heights for the tank with and without baffle wall is studied. They come up with conclusions like the total deformation, shear stresses, and normal Stress are reduced in the case of the tank with baffle walls, the addition of baffle wall reduces the sloshing effect caused due to the convective mass of water and base shear acting at bottom of the wall in case of the tank without baffle is more as compared to base shear in case of the tank with baffle walls.

Admane et. al. (2020) [6], In the study, exploratory and numerical investigation is taken up to get the sloshing effect of fluid contained in ground resting rectangular tank with or without astound divider using electro-magnetic shake table and ANSYS software respectively. An examination of test and numerical outcomes is given as sloshing height for a tank without baffle wall is more than the sloshing height for the tank with baffle wall and base shear calculated at bottom of the wall of a tank without baffle is slightly more as compared to the base shear calculated for the baffled tank.

S Pradeep et. al. (2021) [7], In this research, analysis of various arrangements of baffle walls inside the elevated square water tank with different number of baffles was done to determine the stresses and displacements induced by the sloshing motion of the water tank during earthquake excitations with the help of ABAQUS software. From the analysis, results were obtained like displacement is reduced to 60% in case of the tank with 4 baffle walls, stresses are reduced considerably by 30% and energy dissipation than that of without baffle wall.

Mor & More (2017) [8], The research presents a comparative study of elevated water tanks subjected to dynamic analysis supported on RC framed structure and concrete shaft structure with different capacities and placed in different seismic zones. The research focuses on the dynamic analysis of elevated water tanks as per IS 1893 (Part 2): 2014 and the hydrodynamic effect on the water tank. After analysing the water tank with different capacities, they made few judgments like the areas with high seismic intensity, shaft supported tanks are more susceptible to damage than that of frame supported tanks and sloshing wave height is approximately same for the tanks with the different supporting system, but it differs for tanks as the capacity increases.

Hosseini and Farshadmanesh (2011) [9], In this study they have examined the effect of using multiple vertical baffles in rectangular tanks having different capacities. Tanks having different no. of vertical baffles ranging from 1 – 4 at the upper level of the tank were analysed subjected to both harmonic and seismic excitations with various intensities to find out the effect of scaling factor and effect of baffles on sloshing. Based on the numerical results of this study they concluded that a tank with 2 -3 baffles, equally spaced along the tank's length, can reduce the sloshing effect to a great extent, and using more baffles doesn't alter the results and optimal submerged depth for the baffles depends on the geometric features the tank and the water depth.

Xue and Lin (2011) [10], developed a 3D numerical model using NEWTANK to study sloshing of viscous liquid in a tank with internal baffles of different shapes and arrangements under near-resonant frequency excitation. Virtual boundary force (VBF) method was used to model the internal baffle walls with complex geometries. Experiments in laboratory were conducted for non-linear sloshing in a rectangular tank with and without vertical baffle and concluded that the damping effects of ring baffle are more effective for surge excitation motion than that of pitch excitation, ring baffle is effective in reducing violent liquid sloshing when it is placed near to free surface and increased in width and the analysis shows that the presence of ring baffle can cause the shift of peak response frequency to the lower side.

3. Conclusions

From the literature review, the following conclusions can be drawn:

1. The concrete baffle walls proved to be effective in minimizing the sloshing effect of liquid in the elevated water tank.
2. The incorporation of baffle walls of appropriate height and optimum position reduces the susceptibility of the water tank to fail due to earthquake excitations.
3. From most of the studies, it is cleared that the more the number of baffles inside the tank lesser the sloshing effect.
4. Providing appropriate number of openings in solid baffles proves to be very fruitful in reducing the sloshing of liquid.
5. There is scope to carry out research studies for determining optimum position, number, height, and type of baffle walls in the elevated intze type water tank.

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