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SEISMIC ANALYSIS OF ELEVATED WATER TANK IN A FRAMED BUILDING

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Abstract - *The main purpose of this present work is to study the performance of elevated water tanks in framed building subjected to dynamic loading, considering the effect of sloshing. These paper also provide 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 discussed in the paper. 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 are not performed since it is an analytical comparison of the seismic performance in a framed building with varying number of storey. The analysis of elevated water tank in framed building is carried out using 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.*

***Key Words*: Elevated water tank, Dynamic loading, Time history analysis, Seismic performance**

1. INTRODUCTION

A water tank is used to store water to tide over the daily requirement. In the construction of the concrete structure for the storage of water and other liquids, the imperviousness of concrete is most essential. Tanks are designed as crack free structures to eliminate any leakage. The need for a water tank is for storage of water for use in many applications, drinking water, irrigation, agriculture, fire suppression, agricultural farming, chemical manufacturing, food preparation as well as many other uses. Water tank parameters include the general design of the tank, and choice of construction materials, linings.

Elevated water tanks consist of huge water mass resting at the top of buildings which are the most critical consideration for the failure of the tank during earthquakes. Elevated water tanks are critical and strategic structures and damage to these structures during earthquakes may endanger drinking water supply, cause to fail in preventing large fires and substantial economical loss. Since, the elevated tanks are frequently used in seismic active regions also hence, seismic behavior of them has to be investigated in detail. So there is need to focus the seismic safety of lifeline structure which is safe during the earthquake and also take more design forces. The draft is to make a comparative study on static and dynamic analysis and to optimize the best position of the elevated water tank in a framed building is one of the outcomes of the project. The present study is an effort to identify the behavior of elevated water tank under on different building model and modeling of impulsive and convective water masses inside the water tank using structural software SAP2000.

1.1 Modelling of water inside tank

Spring Mass Model for Seismic Analysis: When a tank containing the liquid with a free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region of tank behaves like a mass that is rigidly connected to the tank wall. This mass is termed as the impulsive liquid mass which accelerates along with the wall and induces impulsive hydrodynamic pressure on tank wall and similarly on base. Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass and it exerts convective hydrodynamic pressure on tank wall and base. Thus, total liquid mass gets divided into two parts, i.e., impulsive mass and convective mass. In spring-mass model of the tank-liquid system, these two liquid masses are to be suitably represented.

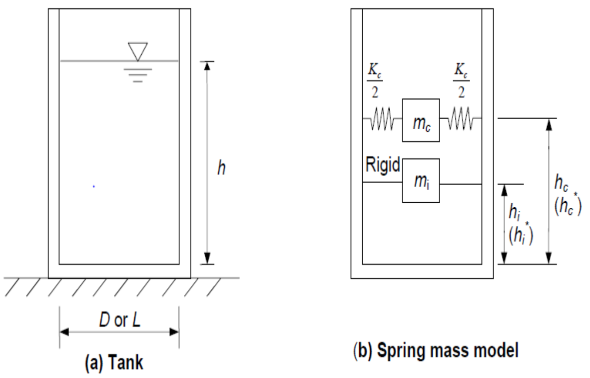

Fig-1: Spring mass model for rectangular tank

2. Methodology

Building model without and with water tank (rectangular and circular shape tank) are modeled and analyzed by under two type of analysis-linear static and non-linear dynamic analysis. Building model with varying number of storeys (3, 6, 9 and 12) without and with the tank is developed. It is necessary to mention here that the design of tank is not a scope of this thesis, but it is the earthquake performance analysis of the structures under study. Hence suitable sections were provided for the modeling of these structures in SAP2000 software and were checked whether they passed the design. All the analyses and the structures on which they are applied are clearly shown below:

Table -1: Classification of Building Models

Linear static analysis	Building model without tank
	Building model with tank Rectangular water tank placed at corner position-represented by letter A Rectangular water tank placed near the centre position- represented by letter B Circular water tank placed at corner position-represented by letter A Circular water tank placed near the centre position-represented by letter B
Time history analysis	Building model without tank
	Building model with tank Rectangular water tank placed at corner position Rectangular water tank placed near the centre position Circular water tank placed at corner position Circular water tank placed near the centre position

Based on the seismic zone of Kerala and soil conditions, the seismic parameters were taken. The analysis software used was SAP2000. The modeling was done in the software for all the conditions, providing the loads. The relevant seismic parameters for modeling and various load combinations were taken from IS 1893(part 1):2002.

The entire process of works done can be listed as follows:

- Fixing the plan of framed building model with varying number of storey (3, 6, 9 and 12)
- Fixing the tank capacity and dimensions
- Analyzing each model using different methods
  1. Linear static analysis
  2. Time history analysis
- Interpretation of result
- Optimization

Design of Elevated Water Tank on Different Building Models Plan to design elevated water tank resting on top of a rectangular building. Rectangular building models are developed with varying number of storey (3, 6, 9, 12 storey) are considered here. Two conditions are:
Case 1: Building model without water tank
Case 2: Building model with water tank
Case 1: Building model without water tank: Rectangular shaped building model are developed with varying number of storeys (3, 6, 9 and 12). Building with regular configurations may be modeled as a system of mass lumped at the floor levels with each mass having one degree of freedom.

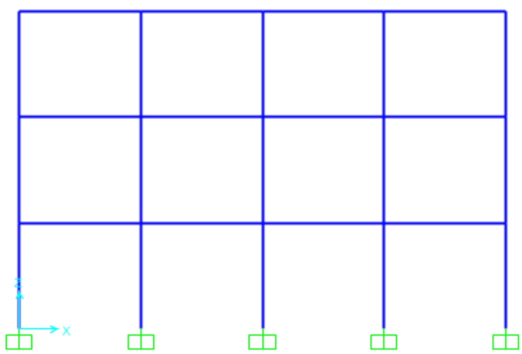

Fig. - 2: 3 Storey RC building configuration

In x direction 4@4m and in y direction 3@4m

- Material used: concrete
- Column: M30 mix
- Beam: M25 mix

- Rebar: HYSD bars
  Case 2: Building model with water tank
- Developed building model with the water tank on varying number of storeys (3, 6, 9, and 12).
- The position of the water tank on top of building – At the corner and other placed near to the centre position of the building.
- The design of elevated water tank – Two type water tank rectangular and circular shape. Water is modeled using spring mass system for non-linear dynamic analysis.

If a closed tank is completely full of water or completely empty, it is essentially a one-mass structure. If, as is usual, the tank has a free water surface there will be sloshing of the water during an earthquake and this makes the tank essentially a two-mass structure. In this case, the dynamic behavior of an elevated tank may be quite different. For certain proportions of the tank and the structure the sloshing of the water may be the dominant factor, whereas for other proportions the sloshing may have the small effect. Therefore, an understanding of the earthquake damage, or survival, of elevated water tanks requires an understanding of the dynamic forces associated with the sloshing water.

3. RESULTS AND DISSCUSSIONS

In the present study, from SAP2000 the seismic response of elevated water tank in framed building has been accomplished by time history analysis. Time history analysis results were tabulated in the form of joint displacement and joint acceleration. It has been observed that there is significant variation in results based on the load case as per IS 1893 (Part1):2002.

Joint Displacement

The maximum values of joint displacement at roof top for 3 storey, 6 storey, 9 storey and 12 storey with and without water tank for El Centro are given in Table 2.

Table 2: Comparison of joint displacement

Storey	Displacement (mm)	
	Without tank	With tank–corner position
3	79.419	28.076
6	162.849	34.168
9	229.043	45.927
12	362.125	57.896

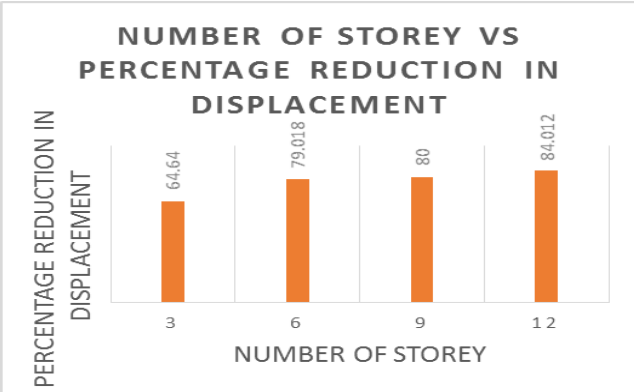

Fig. - 3: Graph showing number of storey Vs percentage reduction in displacement

It can be observed that displacement reduces effectively for earthquake load case when water tank are provided in 3, 6,9,12 storey frame, compared to normal frame. It was observed that water tank in corner position framed building system is more effective in controlling displacement.

Joint acceleration

The maximum values of joint acceleration at roof top for 3 storey, 6 storey, 9 storey and 12 storey with and without water tank for El Centro are given in Table 3.

Table 3: Comparison of joint acceleration

Storey	Acceleration(m/sec^2)	
	Without tank	With tank–corner position
3	4.28919	2.06213
6	5.93206	2.8
9	6.74496	3.1057
12	9.03787	3.31722

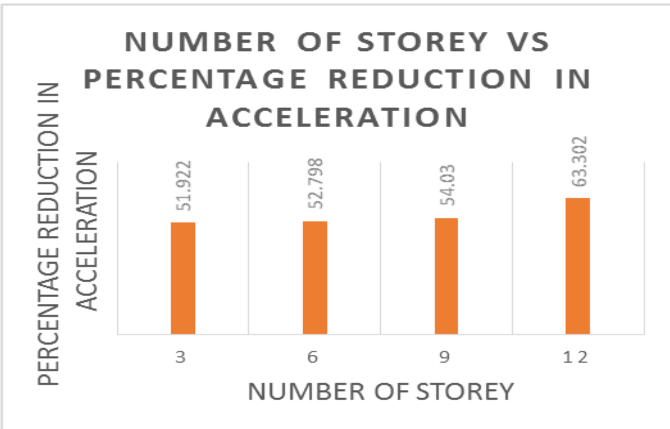

Fig. - 4: Graph showing number of storey Vs percentage reduction in acceleration

4. CONCLUSIONS

On the basis of analytical study the following conclusions can be drawn:
Building model without water tank with varying number of storey (3, 6, 9, and 12) are developed for the study. Also building model with water tank (rectangular and circular shape) placed at two different position (one near to the centre and other at corner position) with varying number of storey(3, 6, 9 and 12) has been developed.
In linear static analysis percentage reduction in joint displacement has been obtained on by comparing building the model with tank and without the tank. 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 linear static analysis best position and shape of the tank will be obtained as rectangular tank placed at the corner position shows better compared to tank when placed near to the centre. In general, certain factors mainly 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. The percentage reduction in joint displacement and joint acceleration seems to be more for 3 storey building model and increases with the increase in 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. For example, a circular tank in a rectangular room means there is going to be a lot of wasted space in that room in the corner that the tank does not cover. Another drawback is the fact that a round tank has no difference in length or width, therefore water circulation can only occur in a circular motion. 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 wall are designed for hoop tension and bending moments.
From both static and dynamic analysis, the best position and shape of the water tank is obtained as rectangular tank placed at the corner positon in a framed building

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