

# International Journal of Innovative Research in Science, Engineering and Technology

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## A Seismic Study on Effect of Water Tank Modelled as TMD

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**ABSTRACT:** Earthquakes are one of nature's greatest hazards, throughout historic time they have caused significant loss of life and severe damage to property, especially to man-made structures. Engineering community is striving hard to innovate different methods that can provide a solution to minimize this damage. The idea of seismic response control of the structures by using TMD's is considered for this study. A tuned mass damper (TMD) is a device consisting of a mass, a spring, and a damper that is attached to a structure in order to reduce the dynamic response of the structure. The frequency of the damper is tuned to a particular structural frequency so that when that frequency is excited, the damper will resonate out of phase with the structural motion. Energy is dissipated by the damper inertia force acting on the structure. Water tanks are integral part of all buildings and they impart large dead load on the structure. This additional mass can be utilized as TMD to absorb the extra energy imparted on the structure during earthquakes. The aim of the present work is analyzing the feasibility of implementing water tank as passive TMD and finding the optimum level of water which would reduce peak response of the structure subjected to seismic forces using SAP2000. The building studied in this work is a reinforced concrete moment resisting frame of three and seven storey designed for gravity and seismic using 1893:2002. In this study the Storey drifts, Base shear, Time period, Storey displacement, were studied and the results obtained were compared with those obtained from others.

**KEYWORDS:** TMD, SAP2000, Water Tank, Time Period, Dynamic Response, Storey Displacement.

### I. INTRODUCTION

Natural calamities fear the man kind since the day first. Earthquake is the most distressing hazard on the earth. An essential requirement of present-day in new trend structural design and assessment of existing structures is seismic hazard extenuation. Seismic ground motions are a major cause for creating damaging effects on Reinforced Concrete (RC) multistory buildings. So far, the exact characteristics of the shaking motion of ground at a particular site cannot be anticipated with certain precision. It is hard to evaluate all factors that strike the overall behavior of a complex structure when subjected to the seismic excitation. The conventional approach to mitigate the seismic hazard is to design the structure itself so strong, sufficient to resist the earthquake forces. But it would be very costly to move it on for the developing countries like India, where the investments and budgets for civil projects are of great concern. An increase in the frequency of occurrence of natural disaster event has been evident for years. Strong vibration and possible collapse of structures during these events can lead to catastrophic human and economical losses. Damping is one of the most important parameters that limit the response of the structures during these dynamic events. Recently, a technique to increase the damping of a building has been developed by attaching one or multiple liquid-fluid tanks to the structures. The sloshing motion of the fluid that results from the vibration of the structure dissipates a portion of the energy release by the dynamic loading and therefore increases the equivalent damping of the structure. These tank devices are referred to as Tuned Liquid Dampers (TLD). In the past few years, a number of TLD was attached to various buildings to reduce the level of vibrations of the structures during their normal operations.

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## II. LITERATURE REVIEW

Since the early 1980s TLD has been investigated by many researchers. Lee et al. (1982) studied effective TLD parameters including liquid height, mass, frequency, and damping for a TLD attached to offshore platforms. Bauer (1984) was among the first researchers who applied TLDs to ground civil engineering structures by introducing a rectangular tank full of two immiscible liquids to decrease structural vibration. Wakahara et al. (1992) and Tamamura et al. (1995) showed the effectiveness of TLDs installed in real structures such as Nagasaki airport tower, Yokohama Marine tower, and Shin Yokohama Prince (SYP) hotel to reduce the structural vibration. Sun et al. (1995) calibrated equivalent mass, stiffness, and damping of TLD using a tuned mass damper (TMD) analogy from experimental data of rectangular, circular, and annular tanks subjected to harmonic base excitation.

Lee et al. (2007) performed a real-time hybrid pseudo dynamic (PSD) test to evaluate the TLD performance. In this method the structure was modeled in a computer and the tank was tested physically. They compared results with the conventional shaking table test and indicated that the performance of the TLD can be accurately evaluated using the real-time hybrid shaking table testing method without the physical structural model.

## III. OPTIMIZATION

For optimization the structure was modeled as lumped single degree of freedom spring-mass system, with mass equal to that of the unit modal mass. The effectiveness of the TMD depends on the proper tuning of the characteristics of TMD to that of the structure. In the present work the mass ratio (mass ratio means mass of the water tank to the mass of the structure) is taken as 25%. These model works as follows, when the main oscillator is requested, the device produces inertial forces proportional to the mass of the TMD, which will exert a reaction on the system in the opposite direction to the main structure's movement. This will result as a decrease in the mains structure's displacements by energy transfer from the primary to the secondary oscillator, and a tendency to increase the TMD's displacements.

## IV. MODELLING

Two framed structures of varying height are considered for the analysis.

Models	No. of Floors	No. of Bays	Floor Height(M)	Bay size(M)	Height of the Tank(M)
M1	G+3	3x3	3	4	2
M2	G+7	3x3	3	4	2

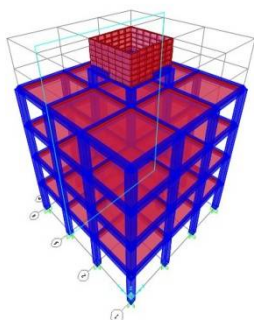


Fig:-Isometric view of Model-1 with tank

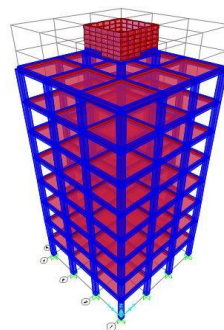


Fig:-Isometric view of Model-2 with tank

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## V. MATERIAL PROPERTIES

Sl.No	Description	Model 1	Model 2
1	Type of structure	RC Frame	RC Frame
2	Grade of Concrete	M25	M25
3	Grade of Steel	Fe 415	Fe 415
4	Density of Concrete	25kN/m <sup>3</sup>	25kN/m <sup>3</sup>
5	Foundation Depth	1.5 m	1.5 m
6	Dimension of Beam	230mmx450mm	230mmx450mm
7	Dimension of Column	450mmx450mm	450mmx450mm
8	Slab Thickness	150mm	150mm
9	Live Load	3kN/m <sup>2</sup>	3kN/m <sup>2</sup>
10	Floor Finishes	1.5kN/m <sup>2</sup>	1.5kN/m <sup>2</sup>
11	Importance Factor	1.0	1.0
12	Seismic zone Factor	0.36	0.36
13	Response reduction Factor	5	5
14	Soil Type	II	II
15	Wall Loads(Exterior)	8.2kN/m	8.2kN/m
16	Wall Loads(Interior)	4kN/m	4kN/m

## VI. ANALYSIS

The Time History and Response spectrum analysis is done in the this study by using Bhuj earthquake data and a comparative analysis results of above mentioned models is done in terms of Time period, Storey Displacements, Storey Drifts, Base shear are presented in this thesis.

## VII. RESULTS AND DISCUSSIONS

In this study two models mentioned below having different water depths in the tank are analyzed. The results are shown in graphical format.

**For the analysis purposes following models are used:**

### MODEL 1: (G+3 STORIED BUILDING)

1. RCC building with Empty water tank at its centre.
2. RCC building with (1/3) water level in the tank.
3. RCC building with (1/2) water level in the tank.
4. RCC building with (2/3) water level in the tank.
5. RCC building with tank full of water.

### MODEL 2: (G+7 STORIED BUILDING)

1. RCC building with Empty water tank at its centre.
2. RCC building with (1/3) water level in the tank.
3. RCC building with (1/2) water level in the tank.
4. RCC building with (2/3) water level in the tank.
5. RCC building with tank full of water.

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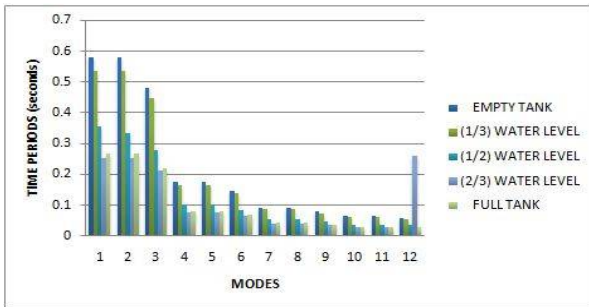


Fig:-Time periods of model-1 in X-direction

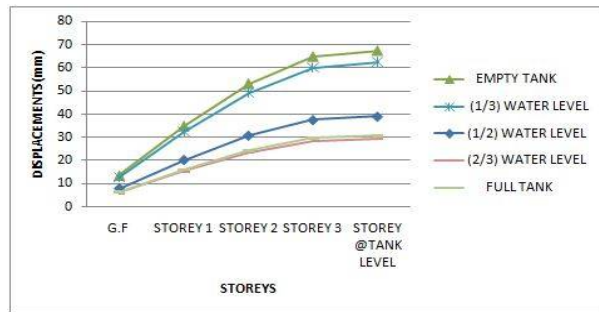


Fig:-Displacements of model-1 in X-direction

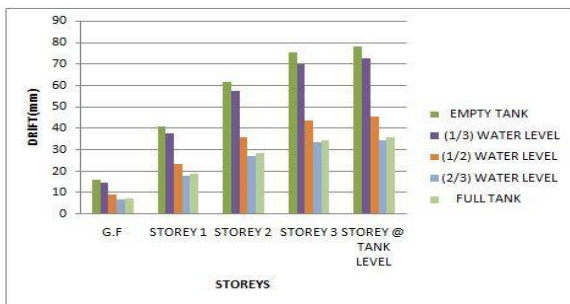


Fig:-Storey drifts of model-1 in X-direction

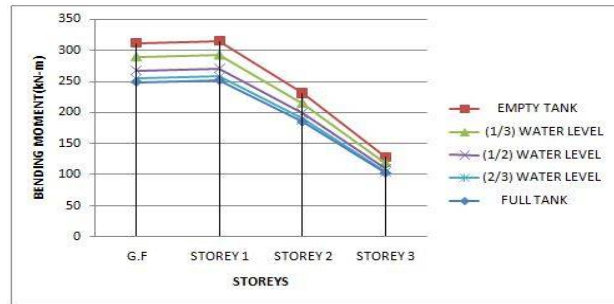


Fig:-Bending moments for model-2 in X-direction

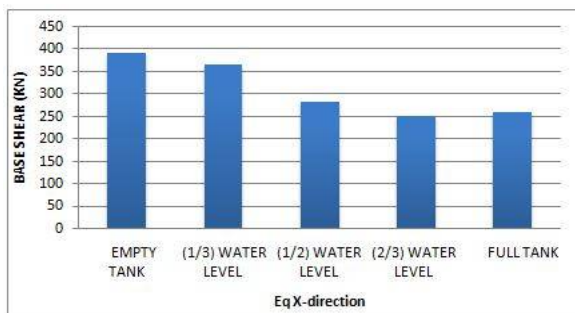


Fig:-Base shears for model-1 in X-direction

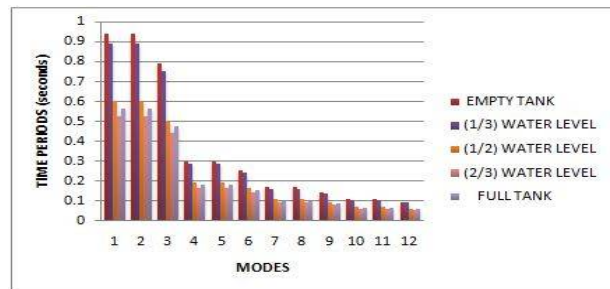


Fig:-Time periods of model-2 in X-direction

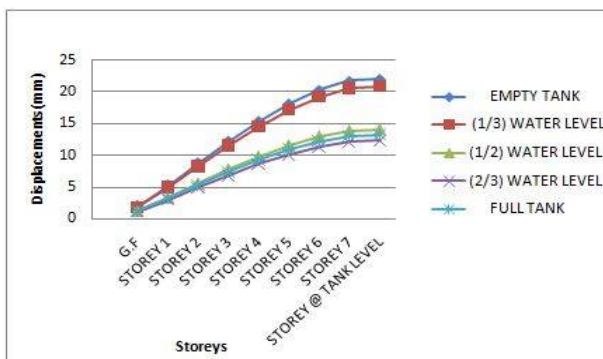


Fig:-Displacements of model-2 in X-direction

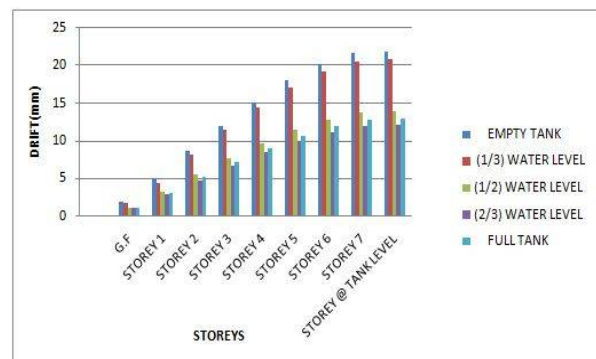


Fig:-Storey drifts of model-2 in X-direction

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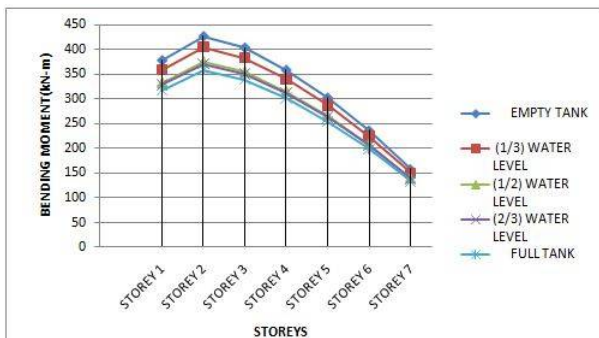


Fig:-Bending moments for model-2 in X-direction

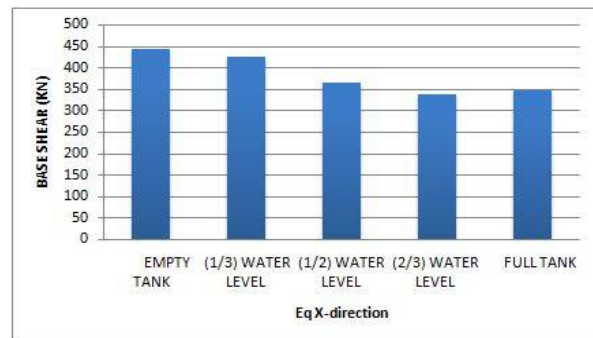


Fig:-Base shears for model-2 in X-direction

### RESPONSE OF STRUCTURE FOR DIFFERENT WATER LEVELS FOR TIME HISTORY ANALYSIS:

The expression of Time History analysis deflection patterns for Model-1, excited by Bhuj earth quake data are represented in the following graphical format:

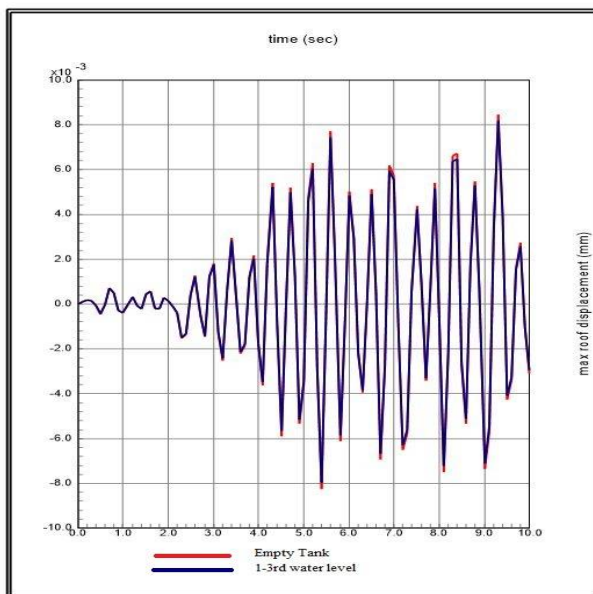


Fig:-Time History response for Empty Tank vs. 1/3<sup>rd</sup> Water level

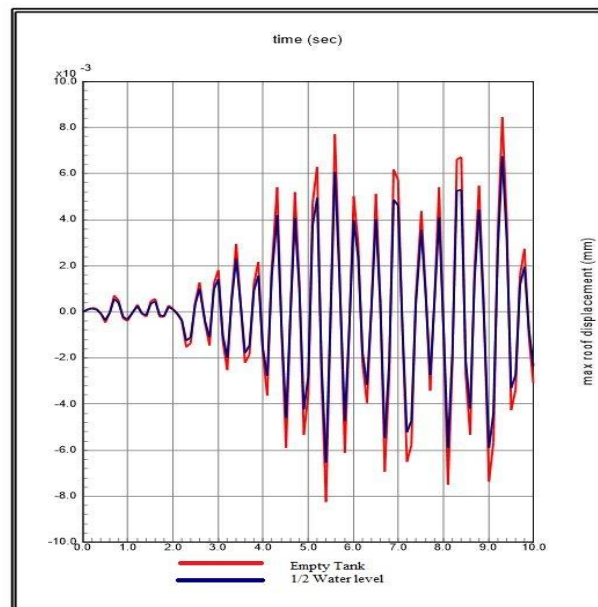


Fig:-Time History response for Empty Tank vs. 1/2 Water level

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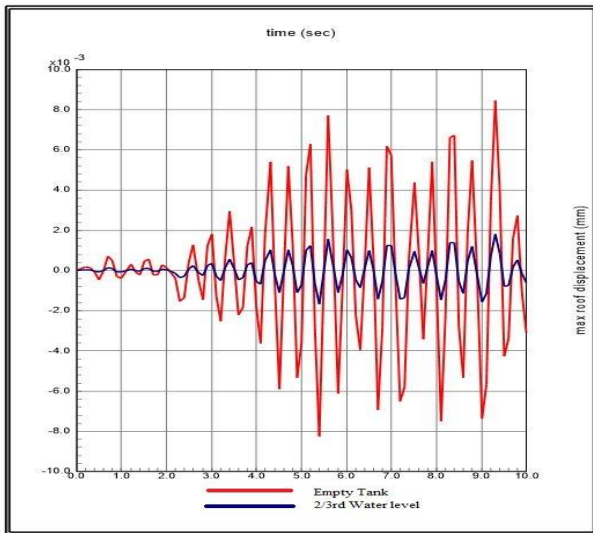


Fig:-Time History response for Empty Tank vs. 2/3<sup>rd</sup> Water level

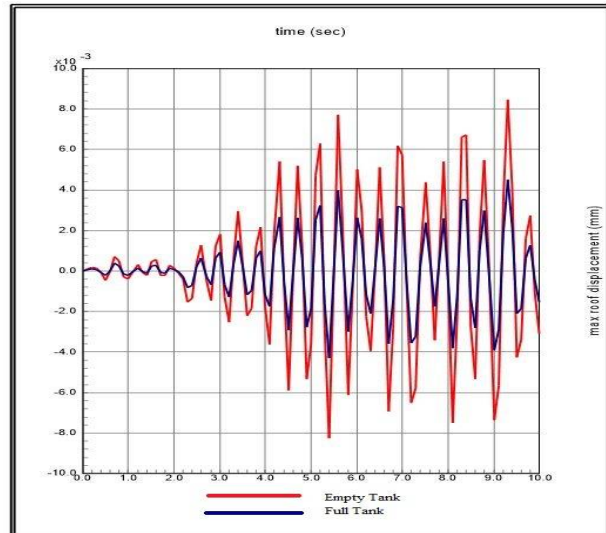


Fig:-Time History response for Empty Tank vs. Full Tank

The expression of Time History analysis deflection patterns for Model-2, excited by Bhuj earth quake data are represented in the following graphical format:

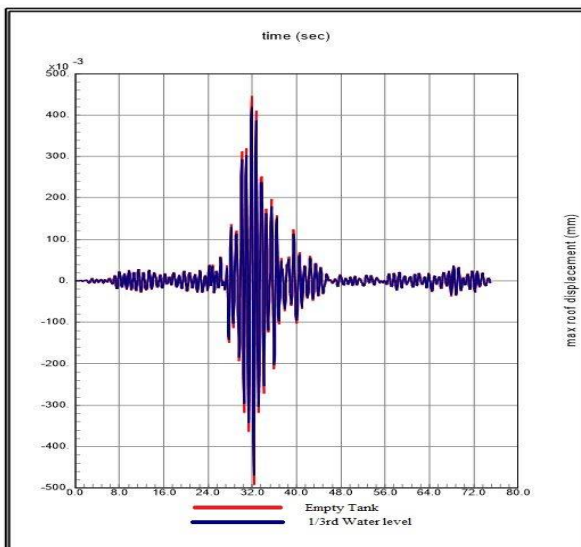


Fig:-Time History response for Empty Tank vs. 1/3<sup>rd</sup> Water level

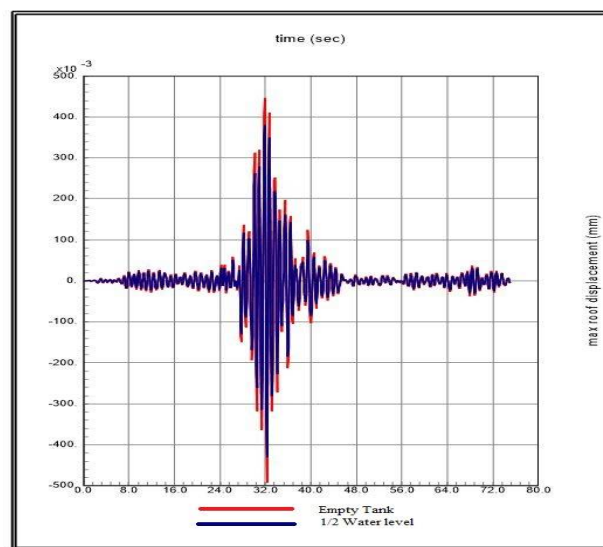


Fig:-Time History response for Empty Tank vs. 1/2 Water level

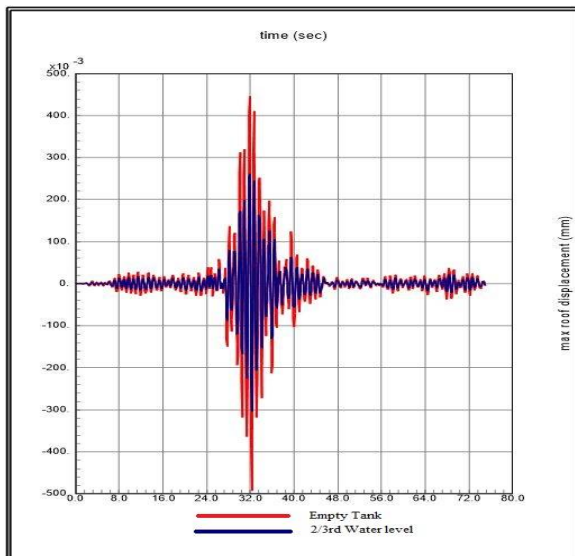


Fig:-Time History response for Empty Tank vs. 2/3<sup>rd</sup> Water level

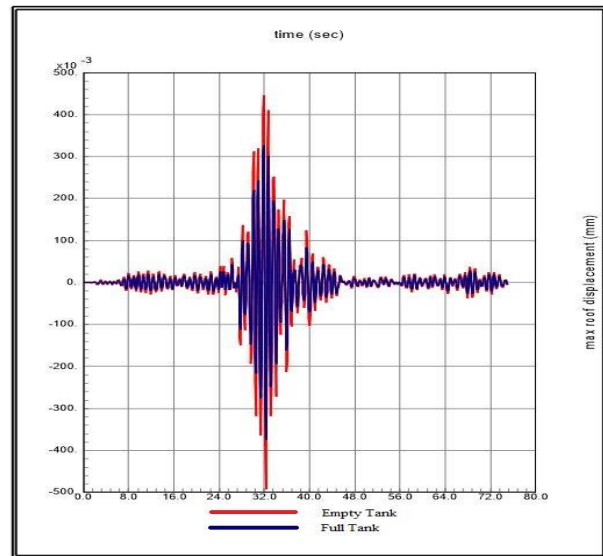


Fig:-Time History response for Empty Tank vs. Full Tank

## VIII. CONCLUSIONS

After the analysis, it has been observed that water tank can serve as passive tuned liquid damper to control the excitations of the structure subjected to earth quakes.

The following conclusions are made from the study:

- Influence of TLD (tank + water) itself could be effective in respect of additional mass on top of building, since model study showed encouraging results for Bhuj earth quake data used in the study.
- The roof displacements, story drifts, time period and base shear has been reduced by 44%, 40%, 38% and 24% respectively for 2/3 level of water tank model compared to other levels. Hence 2/3 is the optimum level of water that should be maintained for effective results.
- Finally, it is concluded that if the level of water in the tank is maintained between (1/2) H to (2/3) H (having mass ratio 25%) it may have the tendency to mitigate the vibrations of RC frame structures under seismic excitations.
- An expected outcome of this study is to develop tools that can be used in designing tuned liquid dampers that can be attached to specific buildings for upgrading their seismic resistance.

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### BIOGRAPHY



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