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Effectiveness of Water Tank as Passive TMD for RCC Buildings

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Abstract: Recent devastating earthquakes around the world have underscored the tremendous importance of understanding the way in which civil engineering structures respond during such dynamic events. Today, one of the main challenges in structural engineering is to develop innovative design concepts to protect civil structures, including their material contents and human occupants from hazards like wind and earthquakes. Among the numerous passive control methods available, the tuned mass damper (TMD) is one of the simplest and most reliable. The common man in a developing country like India may not be in a position to afford for implementing control devices of any sort which may prove uneconomical. Hence an attempt has been made to study the feasibility of utilizing the water tank in the structure to resist seismic forces. The present paper deals with the analytical investigation of G+7 and G+12 storey symmetric and asymmetric, buildings with and without water tank. The seismic performances of a building with and without tank provided with different water level were studied using El-centro earthquake record. The buildings were studied under four conditions, namely, without tank, empty tank, half filled and fully filled tank.

Keywords Passive TMD, Non linear analysis, Symmetric, Asymmetric, SAP2000

1. Introduction

Today there are number of low-rise or medium rise and high rise buildings existing in the world. Mostly these structures are having low natural damping. So increasing damping capacity of a structural system, or considering the need for other mechanical means to increase the damping capacity of a building, has become increasingly common in the new generation of tall and super tall buildings. new generation high rise building is equipped with artificial damping device for vibration control through energy dissipation. The various vibration control methods include passive, active, semi-active, hybrid. Now a day's TMD theory has been adopted to reduce vibrations of tall buildings and other civil engineering structures. A Tuned mass damper (TMD) is a passive damping system which utilizes a secondary mass attached to a main structure normally through spring and dashpot to reduce the dynamic response of the structure. The secondary mass system is designed to have the natural frequency, which depends on its mass and stiffness, tuned to that of the primary structure. Common man is unable to afford such control devices since they prove to be uneconomical. Hence provisions are to be made to use the existing component of building, to reduce the vibrations induced in the building by earthquake and wind. Since the water storage tanks are built-in component of buildings and mostly these are constructed on the top roof level, hence they add dead burden on the structure. During earthquakes, this extra mass can be employed as damper to take over the surplus energy transmitted to the structure. Hemalatha and Jaya (1) carried out analytical investigation to study the feasibility of implementing water tank as passive tuned mass damper using ANSYS. Water tank placed at roof of three and five storey concrete structure were studied. Different conditions of water tank i.e tank empty,1/4th water, 1/2th water, 3/4th water and full tank was studied for four earthquake data, namely, El-centro, Hachinohe, Kobe and Northridge. The results showed that if the tank is tuned properly it can reduce the peak response of structure subjected to seismic forces. Gulve and Murnal (2) conducted study on implementation of water tank as passive tuned mass damper. The tank was placed over 1m high columns on the roof. The behavior of water tank subjected to five earthquake data, namely, El-Centro, Bhuj, Kobe, Chichi and N-Palm was studied under four conditions, namely, building only with damping, empty tank with damping, full tank with damping, and full tank without damping. The results showed that the peak response of structure subjected to seismic forces can be reduced if the tank is tuned properly. Mehboob. *etal.* (3) carried out numerical investigation of water tank as TLD, installed at the roof level of multi-storey building using ANSYS. It was noted, water levels above 0.5h, there is unsettled trend of reduction in peak response. The present work studies effect of water tank fully and partially filled on the response of symmetric and unsymmetric buildings using SAP2000.

2. Materials and Methods

Most elevated tanks are never completely filled with liquid. Hence a two-mass idealization of the tank is more appropriate. For elevated tanks, the two degree of freedom system can be treated as two uncoupled single degree of freedom systems (Figure.1), one representing the impulsive plus structural mass behaving as an inverted pendulum with lateral stiffness equal to that of the staging, *Ks* and the other representing the convective mass with a spring of stiffness, *Kc*. Structural mass m_s, 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.

A building is said to be a regular when the building configurations are almost symmetrical about the axis and it is said to be irregular when it lacks symmetry and discontinuity in geometry, mass or load resisting elements. The building configuration has been described as regular or irregular in terms of the size and shape of the building, arrangement of structural elements and mass. There are two types of irregularities 1) Horizontal irregularities refers to asymmetrical plan shapes (L, T, U and F) or discontinuities in horizontal resisting elements 2) Vertical irregularities referring to sudden change of strength, stiffness, geometry and mass of a structure in vertical direction

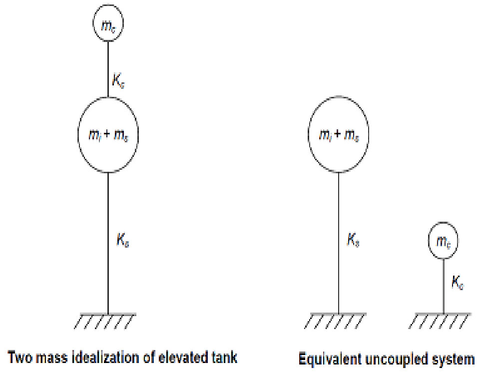

Figure 1. Two mass model

2.1. Modelling of Regular Building

The two models of building G+ 7 storeys and G+12 storeys RCC structures are considered for analysis. Slab is modeled as a rigid diaphragm. Building is symmetric with respect to stiffness and mass. Water tank as tuned mass damper is installed at top of building. Non linear time history analysis is carried out in SAP2000 software using El-centro Earthquake records. The material properties used for the analysis are poisson's ratio -0.16 and density of concrete -2500kg/m^3.

In the present work the water tank is placed at centre of building. The tank had a plan dimension of 3 x 3 m and 2m height for all the models and is placed over 1m high columns. The beam-column supports for the tank are rectangular concrete sections and the walls and roof are also modeled as concrete. The size of water tank is (3 x 3 x 2) m i.e. 18000 liters. The details of the building are shown in Table 1 and that of water tank are shown in Table 2.

Table 1. Details of building

Storey	G+7	G+12
Plan Dimension	9m x9m	9m x9m
Storey Height	3m	3m
Beam Size	0.30m x 0.40m	0.30m x 0.45m
Column Size	0.40m x 0.40m	0.45m x 0.45m
Grade of Concrete	M25	M25

Table 2. Details of water tank

Storey	Size of beam	Size of column
G+7 storey	0.30m x 0.40m	0.45m x 0.45m
G+12 storey	0.30m x 0.45m	0.50m x 0.50m

2.2. Modelling of Plan Irregular Building

The models of building considered for the analysis are G+7 and G+12 storey RCC structures. The building is irregular in plan. The building has bay width of 3m in X and Y direction with 3m storey height. Slab is modeled as rigid diaphragm. The other details of building and water tank are same as that of plan regular building.

In the present work the water tank is placed at centre, side and corner of building. The tank had a plan dimension of 3 x 3 m and 2m height for all the models and is placed over 1m high columns. The beam-column supports for the tank are rectangular concrete sections and the walls and roof are also modeled as concrete. The size of water tank is (3 x 3 x 2) m i.e. 18000 liters. Figure 2 and 3 shows the location of water tank on plan regular and irregular building. And figure 4 and 5 shows elevation of G+7 and G+12 storey building respectively.

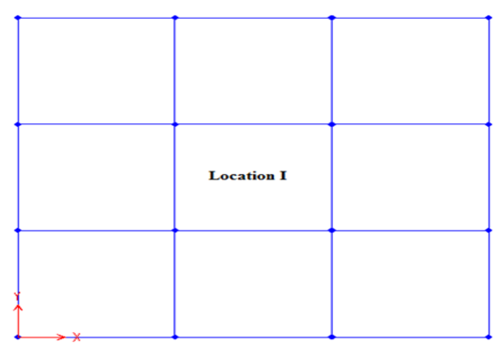

Figure 2. Location of water tank (plan reguar building)

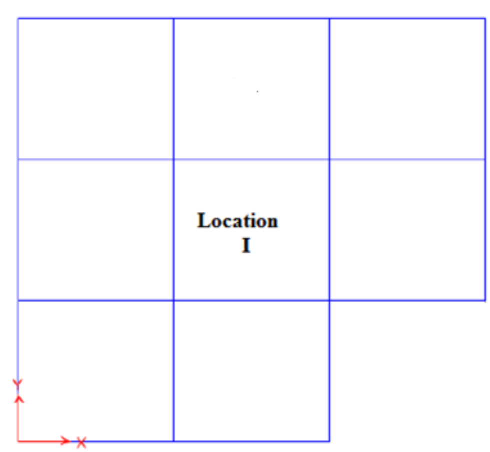

Figure 3. Location of water tank (plan irregular building)

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3. Results and Discussion

The water tank was located at the centre, for plan regular building and near centre of mass for plan irregular building. The water levels in the tank were changed and for each case of water level, the two models were investigated for various levels of water in water tank for El-centro earthquake data. The extreme recorded values of roof displacement are plotted and shown in Figure 6 and 7. Generally it is observed that for G+7 storey plan regular building water tank placed at centre with all water levels are safe whereas for plan irregular building water tank placed near centre of mass with water half filled and fully filled water tank are effective in mitigating response. In G+12 storey plan regular building water tank placed at centre is effective irrespective of any water levels and for plan irregular building half filled and fully filled water tank reduce the response of building. Figure 6 and 7 shows maximum displacement for buildings.

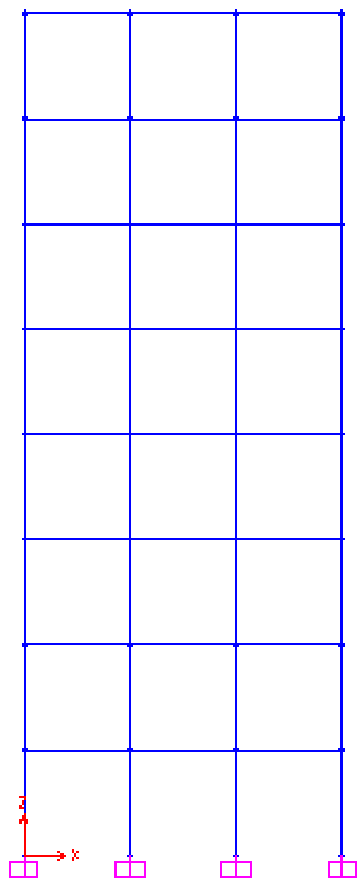

Figure 4. Elevation of G+7 storey building

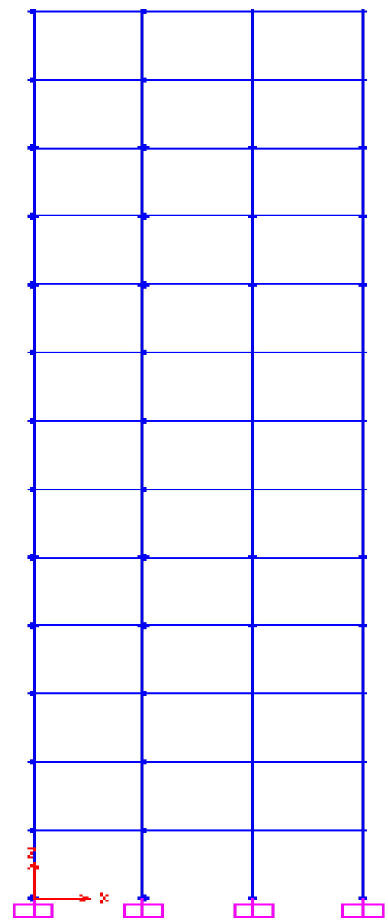

Figure 5. Elevation of G+12 storey building

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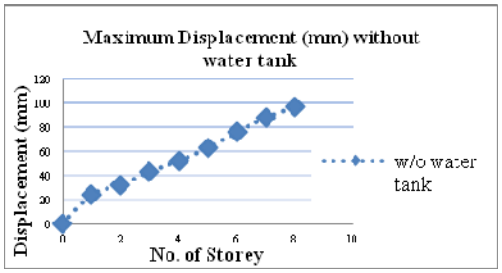
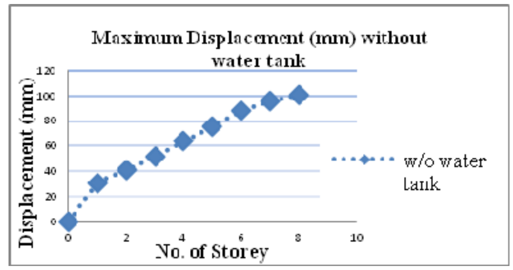
<table>
<tr><th>Conditions</th><th>G+7 Plan Regular building with Water Tank at Centre</th><th>G+7 Plan Irregular Building with Water Tank At Centre</th></tr>
<tr><td>W/o water tank</td><td>
</td><td>
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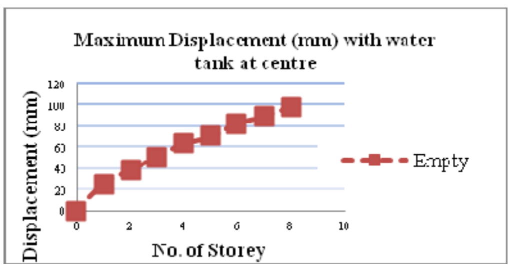
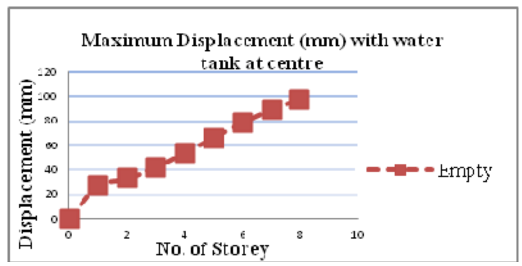
<tr><td>Empty tank</td><td>
</td><td>
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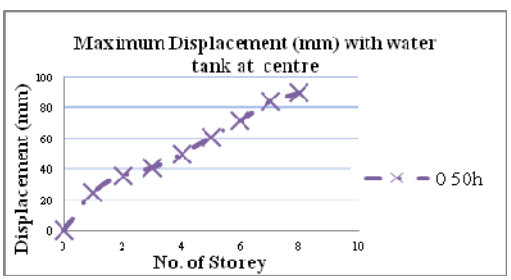
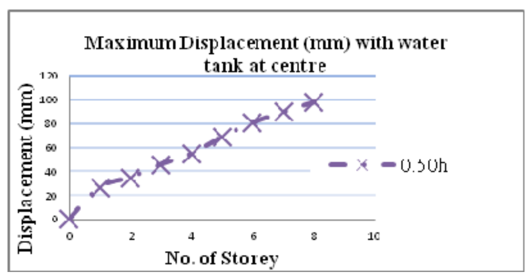
<tr><td>Half filled tank</td><td>
</td><td>
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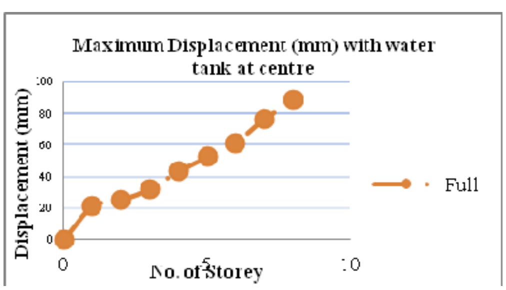
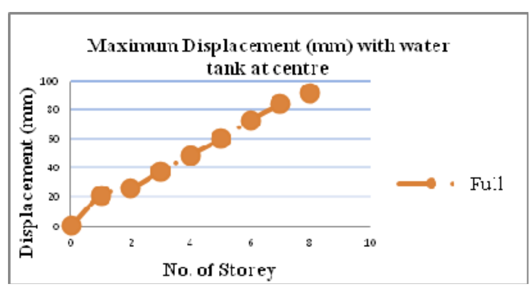
<tr><td>Fully filled tank</td><td>
</td><td>
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Figure 6. Details of displacement of G+7 plan regular and irregular building

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<table>
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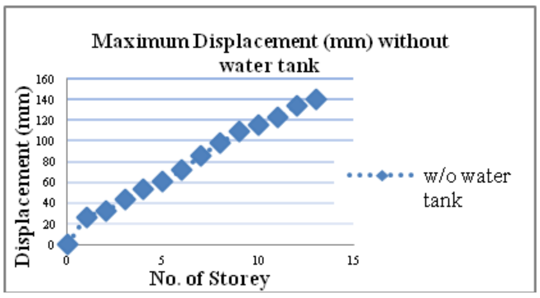
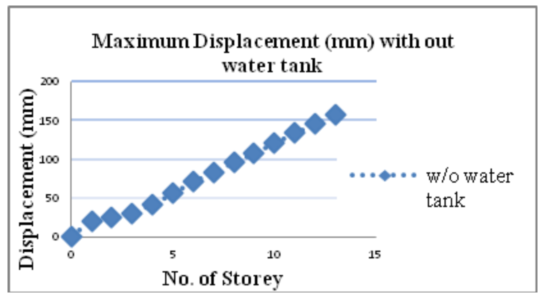
<tr><td>W/o water tank</td><td>
</td><td>
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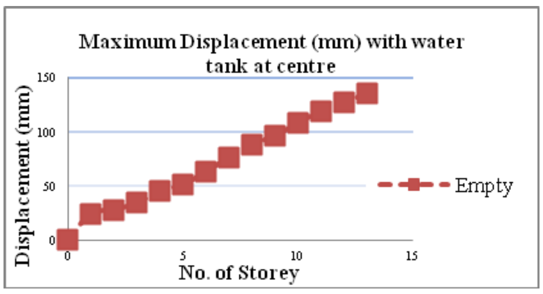
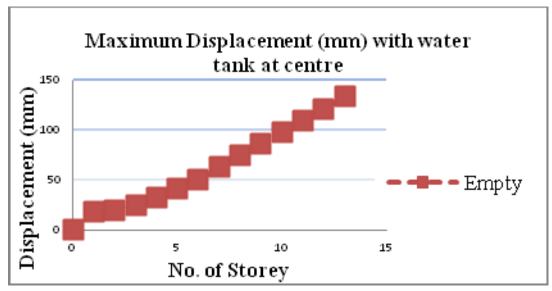
<tr><td>Empty tank</td><td>
</td><td>
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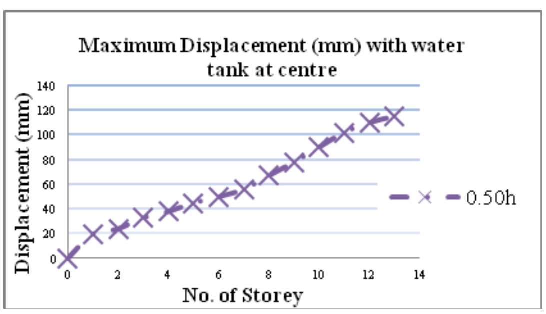
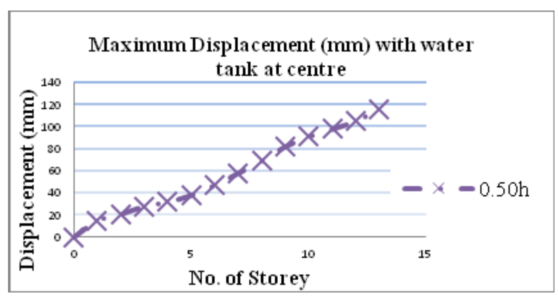
<tr><td>Half filled tank</td><td>
</td><td>
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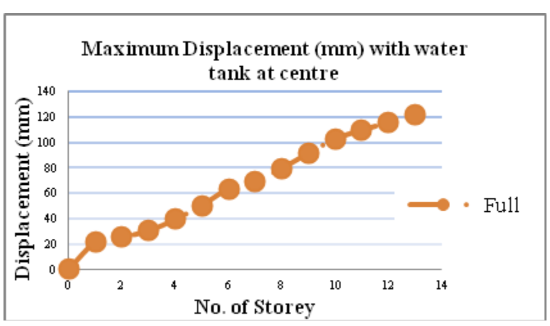
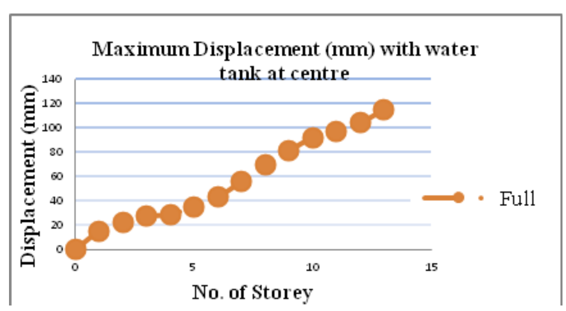
<tr><td>Fully filled tank</td><td>
</td><td>
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Figure 7. Details of displacement of G+12 plan regular and irregular building

4. Conclusion

The behavior of regular and plan irregular building is studied considering different water levels in the tank placed at centre of building. Based on the above study following conclusions are drawn.

- Water tank at top can be designed to serve as TMD provided the parameters i.e., plan location of water tank, water level and mass ratio are tuned properly.
- The structural dynamic response of building is altogether different with and without water tank at top.
- The response results obtained for TMD (tank + water) were encouraging and the TMD was observed to be effective for earthquake data taken for the study, in spite of additional mass installed at the top building as TMD.

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