Evaluation the Impact of Corruption, Tax Burden, and Income on the Size of the Shadow Economy

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Abstract

The present study investigates the behavior of passive control systems or structures using tuned mass dampers (TMD). It also investigates the effect of near fault earthquakes on the performance of control systems. To this end, four- eight, and fifteen storey steel moment resisting frame (MRF) buildings were designed three dimensionally with Tuned Mass Dampers and subsequently modeled in a finite element analysis program — OpenSees, and analyzed diachronically. First, Models that use Tuned Mass Dampers and those that do not use them were analyzed. Then base shear and inter-storey drift were computed in both states. Finally, the effect of the number of stories and the frequency content of near-fault earthquakes on the performance of the structure was investigated.

Keywords:
Passive control of structure, Tuned mass damper, Frequency content, Opensees software

1. Introduction

A major concern of structural engineering is to minimize the damages caused by natural hazards such an earthquake. Earthquake is still an unpredictable hazard in spite of all efforts to make it predictable. That is why it poses a major challenge to structure engineers to find ways to minimize the devastations caused by earthquakes.
There are different approaches to protect buildings against earthquakes.

One approach is to reduce or dissipate energy in order to harness seismic responses [1] known as structural control methods. These methods encompass active, passive, and hybrid (semi-active) systems.

Passive systems are perhaps the most popular ones because firstly, their application and maintenance are easy; secondly, they do not need external force; and thirdly, their mechanism is quite easy. Tuned Mass Damping is one of the applicable techniques used for this purpose [2, 3]. A number of studies have looked into the applicability of this technique, while the technique is being increasingly used in structural engineering.

2. Choosing Near-fault earthquake (NFE) records

Kocaeli, Chi-Chi earthquakes, and Northridge earthquakes revealed the vulnerability of existing steel buildings where the fault rupture propagates with a velocity close near-fault earthquakes. Thus, it is vital to find ways to reduce damages to buildings in such cases [4]. Maximum velocity and generation of long pulses cause extensive damage, which makes the resonance phenomenon very probable [5]. Although there are important differences between near-fault and far--fault earthquakes, most researchers have ignored near-fault earthquakes. Therefore, it is very important to study near-fault earthquakes to find ways to limit the amount of damage caused by them. The present study has chosen seven near-fault earthquakes (See table 1) to investigate their effects on selected structures that have been affected by them.

<table>
<thead>
<tr>
<th>No.</th>
<th>Earthquake Name</th>
<th>Year</th>
<th>Station Name</th>
<th>Earthquake Magnitude</th>
<th>Site condition</th>
<th>PGA [g]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>USG S Description</td>
<td>X Dir.</td>
</tr>
<tr>
<td>1</td>
<td>Kocaeli, Turkey</td>
<td>1999</td>
<td>Arcelik</td>
<td>7.4</td>
<td>B  Shallow (stiff) soil</td>
<td>0.218</td>
</tr>
<tr>
<td>2</td>
<td>Chi-Chi</td>
<td>1999</td>
<td>CHY029</td>
<td>7.6</td>
<td>B  Shallow (stiff) soil</td>
<td>0.277</td>
</tr>
<tr>
<td>3</td>
<td>Tabas, Iran</td>
<td>1978</td>
<td>Dayhook</td>
<td>7.4</td>
<td>B  Shallow (stiff) soil</td>
<td>0.406</td>
</tr>
<tr>
<td>4</td>
<td>Kobe</td>
<td>1995</td>
<td>Shin-Osaka</td>
<td>6.9</td>
<td>D  Deep broad</td>
<td>0.243</td>
</tr>
</tbody>
</table>
In order to take the frequency content of velocities into account, first in every record the greater component of PGA has been scaled to 0.45 [5]. Then the smaller component of the same earthquakes has been multiplied by the same value. In order to find the worst case scenario the stronger component of the earthquake has been applied in the direction in which the structure is less rigid i.e., the X axis in this study.

1. Designing and modeling Tuned Mass Dampers

In TMD mass is normally defined as a proportion of the effective mass of the first mode for control which the damper is designed (μ). The motion frequency of the damper is defined as a proportion of the same case. ζ_{TMD} coefficient is chosen somewhat arbitrarily, though it should be practical and realistic (see table 2). The followings help to determine the features of TMD [6]. The values for the following parameters should be specified in advance as done below.

\[ \mu = 0.02 \quad \gamma_f = 0.98 \quad \xi_{TMD} = 0.1 \]
Table 1. Features of structural TMD

<table>
<thead>
<tr>
<th>Model</th>
<th>Dir.</th>
<th>$M_n^*$ [kg]</th>
<th>$\omega_n$ [rad/sec]</th>
<th>$\omega_{TMD}$ [rad/sec]</th>
<th>$m_{TMD}$ [kg]</th>
<th>$K_{TMD}$ [N/m]</th>
<th>$C_{TMD}$ [N.sec/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Storey</td>
<td>X</td>
<td>328423</td>
<td>6.89</td>
<td>6.75</td>
<td>13136.92</td>
<td>599810.30</td>
<td>17753.48</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>331723</td>
<td>7.47</td>
<td>7.32</td>
<td>13268.94</td>
<td>710336.84</td>
<td>19416.92</td>
</tr>
<tr>
<td>8 Storey</td>
<td>X</td>
<td>640622</td>
<td>4.1</td>
<td>4.04</td>
<td>20692.60</td>
<td>417742.38</td>
<td>25624.88</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>643121</td>
<td>4.39</td>
<td>4.32</td>
<td>22235.54</td>
<td>480487.68</td>
<td>25724.86</td>
</tr>
<tr>
<td>15 Storey</td>
<td>X</td>
<td>1188470</td>
<td>2.3</td>
<td>2.25</td>
<td>47538.78</td>
<td>326698.96</td>
<td>24924.58</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>1180493</td>
<td>2.43</td>
<td>2.38</td>
<td>47219.72</td>
<td>371462.44</td>
<td>26488</td>
</tr>
</tbody>
</table>

$M_n^*$ is the effective mass for the nth mode

Two nodes with identical features were defined to model TMD in OpenSees. A rigid link beam links the first node to the main node of the roof storey, which is the center of the roof mass. [7]. The mass of the damper was allocated to two the second node as transferred masses in directions x and y. Two uni-axis materials- one as an elastic material with the rigidity of the damper spring and the other as viscous material with its own damping properties- were defined. Then a Zero Length Element containing both viscous and elastic materials linked the first node to the second, in which case both the viscous and the elastic material worked in parallel. The specified degrees of freedom for both nodes were defined so that they work in sequence relatively. Figure one depicts a schematic representation of TMD in direction x.
2. Designing and modeling structures

First, 4, 8, and 15 storey buildings were designed as depicted in figure 2 under focal and lateral loads through threshold level scenario in ETABS, a software package for the structural analysis and design of buildings [8]. Then, the structural elements and sections were modeled in OpenSees. Finally, they were subjected to a set of near-fault records. Figure 3 represents one of the 8 storey building frames.

Figure 3. The plan

Non-linear beam columns were used to define elements in OpenSees. A fiber section is allocated to the non-linear beam-column, which creates plasticity throughout the element. [7]. Integrals were calculated in ten points throughout the element on the basis of Gauss-Lobatto rule, which is default rule in OpenSees at two obligatory points at the beginning and the end of the element. OpenSees is capable of calculating integrals in ten points for every element. The higher the number of point, the more accurate the results, and the longer they take to obtain.

A rigid diaphragm was used to model the floor rigidity. In order to define the rigid diaphragm, at the level of each storey, one node was defined as main node in the center of the storey plan (rigidity center). The, all nodes in the same storey were linked to the main node through the rigid diaphragm. Degrees of freedom are free for the transferred movement in directions x and y and circularly around y axis (the vertical axis). For the rest, they are closed.

5- Comparing Natural Periods

The models for natural periods created by OpenSees were compared with those created by ETABS to verify their accuracy. The results for the first mode are presented in table 3, which shows identify of the two models.
Table 3. Natural periods for the first mode of the structure

<table>
<thead>
<tr>
<th>Model</th>
<th>$T_1(ETABS)$ [Sec]</th>
<th>$T_1(OPENSEES)$ [Sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Storey</td>
<td>0.9125</td>
<td>0.9275</td>
</tr>
<tr>
<td>8 Storey</td>
<td>1.5389</td>
<td>1.5606</td>
</tr>
<tr>
<td>15 storey</td>
<td>2.6933</td>
<td>2.6968</td>
</tr>
</tbody>
</table>

6-Results

The drift ratio is defined as the ratio of maximum lateral drift to total height of the specimen under the earthquakes in specified in table 1. drift ratio can be in the X-direction or Y direction or XY direction. Figures 4 to 6 depict the highest mean drift ratios for the four storey structure in control an uncontrolled cases.
The three dimensional 8 storey building model was subjected to a set of near-fault records analysis. Figures 7 to 9 depict the highest mean drift ratios for the four storey structure in control an uncontrolled cases.

Given the fact that with an increase in the number of floors, the higher modes will show higher effects, the fifteen storey steel moment resisting frame (MRF) building was analyzed three dimensionally with tuned mass dampers and subsequently modeled in finite element analysis program — OpenSees, and analyzed diachronically. Figures 10 to 12 depict the highest mean drift ratios for the four storey structure in control an uncontrolled cases.
7. Conclusions

Given the fact that TMD's frequency is tuned proportionate to the dominant modes of the structure (normally the first mode), when this frequency is induced, TMD begins to resonate in a phase outside the range of the structure, dissipating energy through the inertia force imposed on the structure. The more the number of the floors is, the more important the effect of the higher modes become, which in turn decreases the effective mass of the first floor and make dampers less efficient. Since the frequency features of possible earthquakes, and the dynamic features of the structure such as natural frequencies, and the damping of different modes are unpredictable, it is advisable to use more TDMs with similar to close frequencies in order to cover a larger range of major frequencies of the structure.

The results of this study revealed that using TDMs only in one direction will not decrease seismic responses in other directions. In some case it even leads to an increase in the seismic responses. Therefore, it can be concluded that the use of TMDs in different directions of the structure will help to control seismic activities.

The results shows that inter-story drift in the four storey building was higher than that in the 8 or 15 storey buildings Near-fault earthquake (NFE) records. This is perhaps due to the effect of...
of the frequency features of the near-fault earthquakes, which have a high frequency. Since a four storey structure has a high frequency, too, resonance phenomenon might follow, increasing seismic responses in such buildings.

8-References


