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Seismic Response Reduction by Pendulum Tuned Mass Dampers on Regular High Rise RC Building

Amrutha T P, Amritha E K

Abstract— Vibration's created due to various human activities and natural phenomenons adversely affect building and its occupants. To overcome these problems various types of dampers have been used. Aim of this study is to understand performance of passive pendulum tuned mass damper (PTMD) in response control of a regular RC building during an earthquake. Effect of TMD mass ratio variation on response reduction is also accounted in this study. Fast non linear analysis is performed using SAP2000 V 19 to understand response of structure during a seismic action. Response control is analyzed on regular building with and without damper

Keywords- Fast Nonlinear Analysis, Mass Ratio, Pendulum Tuned Mass Damper, Response reduction, Vibration.

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1 Introduction

EARTHQUAKE can be defined as a process in which there is sudden release of stress waves and large amount of energy due to violent tremor caused to earth's crust. Sever damages occur on building and its surroundings due to seismic excitation. Damages caused by an earthquake is dependent on many factors like site conditions such as characteristics of soil, ground conditions, water table and topography etc.

Structural stability and integrity will be affected due to seismic events; these shortcomings could be overcome by providing retrofitting techniques. Retrofitting technique enables us to make the structure resistant to earthquakes and other natural calamities, while certain other techniques enables to rehabilitate and repair damaged structure

Vibration mitigation should be done to overcome the problems caused by seismic excitation. This could be done by modifying structural mass, stiffness and inherent damping of structures. Tuned mass damper (TMD) is a device which could be used to control vibrations by varying above mentioned parameters. It consists of mass element, a spring element to modify the stiffness and damping element to dissipate vibrations

TMD is a harmonic absorber tuned to structures natural frequency, when excitation of structure occurs near to the tuned frequency the damper resonates and move out of phase and dissipate the vibration energy through damping element attached to TMD. Different types of TMDs are currently used around the world. Most widely used are passive TMD (translational TMD, pendulum TMD), semi active TMD and active TMD. Currently TMDs are widely used in automobiles and vehicles, bridges and buildings to control vibration induced damages.

2 Methodology

The software used in the study is SAP2000 v 19. Building is a G+19 storied R.C structure having 5 bays in X and Y direction with fixed support conditions. Non linear time history analysis and modal analysis is performed following code provisions of IS 1893:2016.

Study is conducted on R.C structure with and without Pendulum TMD (PTMD). PTMD is modeled as simple pendulum, which is tuned to structures fundamental time period. Study is conducted by varying mass ratio (μ). Mass ratio is the ratio between mass of damper (md) to total mass of structure (M). 2%, 4%, 6% and 8% are the mass ratio's considered in this study.

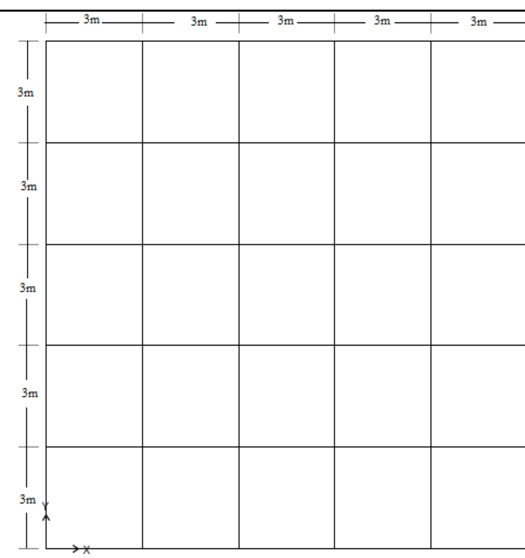

Fig. 1 Plan of Regular RC Case Study Bilding

- *Amrutha T P is currently pursuing masters degree program in Structural Engineering in Universal Engineering College, India,. E-mail: amruthatp111@gmail.com*
- *Amritha E K is currently working as assistant professor at Universal Engineering College, India, E-mail: ekamritha@gmail.com*

TABLE 1
BUILDING PROPERTIES

Number of bays in X and Y direction	5
Storey height	3.5m
Bay length in X and Y direction	3m
Number of stories	G+19
Material Properties	
Grade of concrete	M30
Grade of steel	Fe 415
Member Dimensions	
Slab thickness	.150m
External and internal wall	.23m
Column	.750x.500 m
Beam	.300x.450 m
Types of Load and their Intensities	
Live load on all floors	3 kN/m^2
Floor finish	1kN/m^2
Live load on roof	1.5kN/m^2
Roof finish	1kN/m^2
Seismic zone	Zone V
Soil type	Medium
Importance factor	1
Zone factor	.36
Response reduction factor	5

Time history analysis is performed with earth quake's time history data recorded at recording stations. Displacement and inter storey drifts due to earthquake on the building are analyzed, its variations when a PTMD attached to the structure is studied.

TABLE 2
EARTHQUAKE DATA CONSIDERED IN THE STUDY

Earthquake name	Year	Station name	Magnitude
Superstition Hills	1987	Poe Road	6.54

TABLE 3
DESIGNED DAMPER PARAMETERS

Mass ratio	Mass of damper(kg)	Stiffness U2 of damper (kN/m)	Stiffness U1 of damper (kN/m)	Length of PTMD
.02	228962	1069.57	1200000	2.1m
.04	457923	2139.155	2300000	
.06	686885	3208.733	3300000	
.08	915846	4278.311	4400000	

3 RESULTS

Cyclic motion at the base of the building due to seismic forces creates responses which are dynamic in nature. Output obtained after performing modal analysis helps to understand behaviour of the structure. Response of the building is dependent on dynamic properties such as time period, mode shape, modal mass participating factors etc

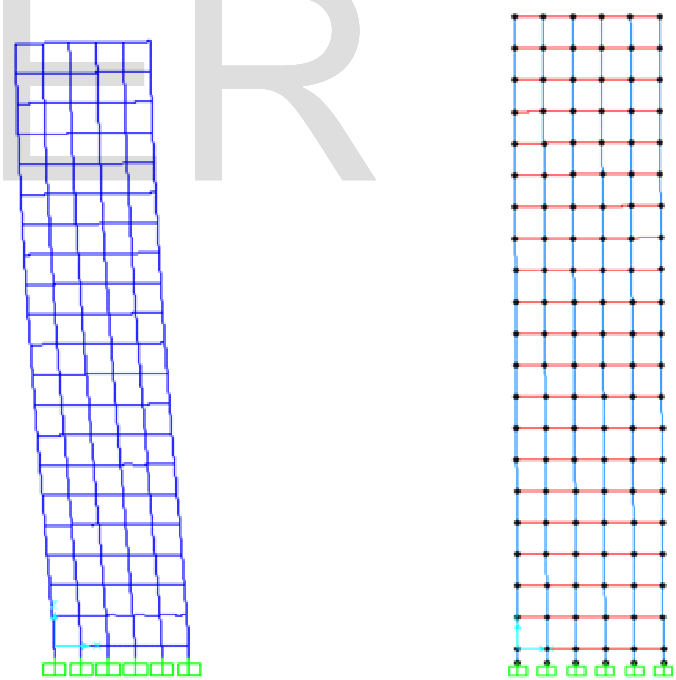

Fig.2 (a) Fundamental Modeshape of Bulding without TMD

Fig.2 (b) Fundamental Mode Shape of Building with TMD

TABLE 4
TIME PERIOD OF THE BUILDING

mode	With out TMD	mass ratio .02	mass ratio .04	mass ratio .06	mass ratio .08
1	2.906	3.414	3.739	4.028	4.293
2	2.697	3.348	3.672	3.960	4.223
3	2.315	2.720	2.689	2.673	2.664
4	0.940	2.573	2.539	2.522	2.511
5	0.861	2.314	2.314	2.314	2.314
6	0.761	0.938	0.937	0.936	0.935
7	0.528	0.860	0.858	0.858	0.857
8	0.474	0.761	0.761	0.761	0.761
9	0.445	0.5276	0.527	0.529	0.608
10	0.367	0.474	0.474	0.527	0.527
11	0.324	0.445	0.445	0.474	0.474

TABLE 5
DISPLACEMENT OF THE BUILDING

height (m)	With out TMD	mass ratio .02	mass ratio .04	mass ratio .06	mass ratio .08
0	0.0028	0.0025	0.0025	0.0025	0.0025
3.5	0.022	0.021	0.020	0.0200	0.019
7	0.046	0.043	0.041	0.0404	0.039
10.5	0.069	0.065	0.062	0.060	0.059
14	0.092	0.086	0.082	0.079	0.077
17.5	0.115	0.107	0.101	0.097	0.095
21	0.136	0.126	0.119	0.114	0.111
24.5	0.156	0.145	0.137	0.131	0.127
28	0.177	0.163	0.154	0.147	0.143
31.5	0.197	0.182	0.171	0.164	0.160
35	0.218	0.201	0.189	0.1814	0.176
38.5	0.239	0.220	0.207	0.197	0.1917
42	0.259	0.238	0.223	0.2136	0.2067
45.5	0.278	0.255	0.239	0.227	0.2202
49	0.295	0.270	0.252	0.2402	0.2315
52.5	0.310	0.283	0.264	0.2503	0.2407
56	0.324	0.295	0.274	0.2591	0.248
59.5	0.338	0.307	0.284	0.267	0.255
63	0.350	0.318	0.293	0.274	0.261
66.5	0.361	0.327	0.3006	0.286	0.266
70	0.369	0.334	0.306	0.285	0.269

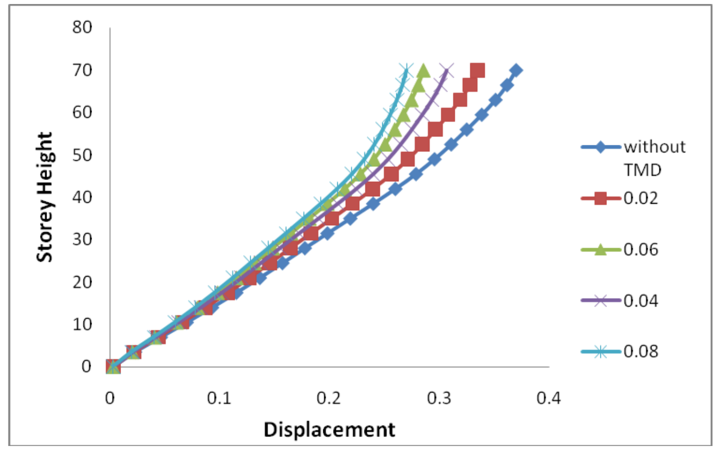

Fig.3 Storey Height V/S Displacement Graph

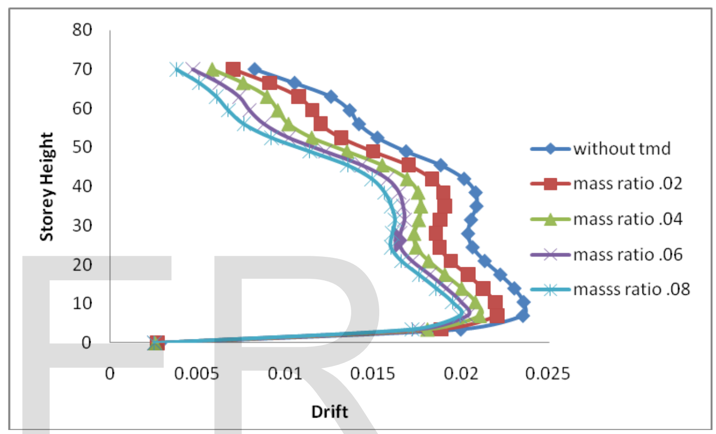

FIG.4 STOREY HEIGHT V/S DRIFT GRAPH

4 DISCUSSIONS

When earth quake strikes a structure large unwanted vibrations are induced in the structure. These vibrations can lead to severe damage and even collapse of structure. Since maximum displacements are observed at top storey of the structure, for better response control PTMDs are installed at top storey. Since fundamental frequency is dominant during a building's response for maximum response reduction PTMDs are tuned to first mode of vibration. Dissipation of energy is by movement of the pendulum out of phase from its initial position. Inter storey drift are also found to be reduced by the installation of PTMD due to dissipation of energy. Variation of mass ratio from .02 to .08 showed an improvement in response reduction. PTMD with .06 Mass ratios showed better response reduction than other mass ratios.

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5 CONCLUSIONS

By installing PTMD on the structure 10 to 25% top storey displacement reduction was observed. Similar reduction in inter storey drift was also observed. From this study it could be concluded that PTMD is an effective retrofitting technique. Installation of PTMD helps in overcoming Sevier damages caused during an earthquake. Discomfort of the occupants can be avoided by installation of TMD

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