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A Study on Vibration Control of Framed Structures Due to Seismic Excitation Using Tuned Mass Damper

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Abstract— Current trends in construction industry demands taller and lighter structures, which are also more flexible and having quite low damping value. As a result these structures will be subjected to vibrations of larger amplitudes under earthquake. This increases failure possibilities and also problems from serviceability point of view. Tuned Mass Damper (TMD) is a passive control device which absorbs energy & reduces response of vibration. This paper addresses the usefulness of incorporating soft storey to function as TMD in controlling the structural response. An attempt is made to find the effective mass ratio which gives the least displacement of the building. Here a six storeyed regular building is proposed to be analysed using SAP2000 v 16 with Tuned Mass Dampers (TMD) and without any damping device. Tuned Mass Dampers with varying mass ratios of 2%, 3% and 5% was applied. Non-linear time History Analysis was carried out by applying standard earthquake ground accelerations. A comparative study was done

Index Terms— Non Linear Time History Analysis, SAP2000 v14, Soft storey, Tuned Mass Damper.

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1 Introduction

The need for construction of taller buildings is increasing day by day. These structures are flexible and constructed as light as possible and which have low value of damping. As a result these structures will be subjected to vibrations of larger amplitudes under wind and earthquake. This vibration creates problem to serviceability requirements of the structure and also reduce structural integrity leading to possible failures. Several techniques are now in use to reduce wind and earthquake induced structural vibration. The control of structural vibrations produced by earthquake or wind can be done by various means such as modifying rigidities, masses, damping, or shape, and by providing passive or active counter forces. Passive tuned mass dampers are widely used to control structural vibration under wind load but its effectiveness to reduce earthquake induced vibration is still in emerging status. Thus a study on vibration control of framed structures subject to earthquake using tuned mass dampers (TMD) is important. In this paper soft storey is used as TMD in a multistory RCC building frame, and non-linear time history analysis is carried out using SAP 2000.

Bakre, S.V. (2002), illustrated that weak soft storeyplaced at top of building decreases the seismic response to a great extend. According to Thawre, R.Y (2004), increase in percentage of mass ratio of TMD increases the effectiveness of TMD. Pinkaew T., Lukkunaprasit P. And Chatupote P. (2003) investigated the effectiveness of TMD under ground motion.Sadek, F (1997), found that for a TMD to be optimum, its natural frequency should be very close to the natural frequency of the structure and its damping ratio should be more that of the structure

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2 VIBRATION CONTROL

2.1 Tuned Mass Damper

Tuned mass damper is a passive control device. The TMD concept was first applied by Frahm in 1909, to reduce the rolling motion of ships as well as ship hull vibrations. A tuned mass damper is simply a mass, spring, damper system. Figure shows a typical tuned mass damper.

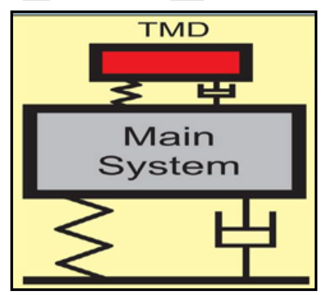

Fig.1Tuned Mass Damper

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.

2.2 Soft Storey

When sudden change of stiffness takes place along the building height, the storey of which the drastic reduction of stiffness is observed is known as soft storey.

- As per IS-1893:2002 (part I)

A Soft Storey is one in which the lateral stiffness is less than 70

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percent of that in the storeyimmediately above/below or less than 80 percent of the average lateral stiffness of the three storeys immediately above/below

2.3 Time History Analysis

Here non-linear time history analysis is done using finite element software SAP 2000. At first three earthquake ground motion data of Bhuj, and Uttarkashi are applied and analyzed.

Since the results computed by the nonlinear dynamic procedure can be highly sensitive to characteristics of individual ground motions, the analysis should be carried out with more than one ground motion record. This is also true for the linear dynamic analysis. FEMA 356 provides guidelines regarding the required number of ground motions that should be used for dynamic analysis. Here 25 earthquakes with different intensities are applied to the building and analyzed.

3 MODELLING AND ANALYSIS

3.1 Analysis Software

For the present study the software SAP 2000 is used and the salient features of the same are presented.

The following elements are expected to be used in the analysis

- Frame elements

It is used to model beams, columns, braces, and trusses

- Shell elements

A shell element is used to model walls, floors, and other thin-walled members.

3.2 Building Description

(i). Structural Configuration

It is a rectangular building with 6 storeys. The storey height is 3m.

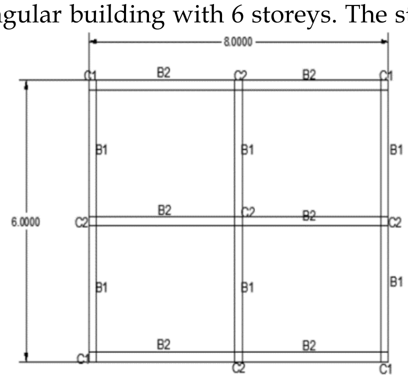

Fig.2 Plan of the building

(ii). Loads Considered

<u>Materials</u>

Grade of concrete – M20
Grade of steel – Fe415

<u>Dead Loads (Unit Weights)</u>

Masonry – 21.2 KN/m3
Concrete - 25 KN/m3
Steel - 78.54 KN/m3

<u>Imposed loads</u>

Floor loads - 4 KN/m2
Roof loads - 1.5 KN/m2

TABLE1: Dimensions of structural elements

Sl. No	DIMENSION
1	C1 – 230x230 mm
2	C2 – 230x400 mm
3	B1 – 230x400 mm
4	B2 – 230x400 mm
5	Slab- 100 mm thick

Initially the grid sections are defined according to the building dimensions. Then the properties of the material as well as the beam and column properties were defined. Then the required building was drawn using the beam, column and slab sections that were defined earlier. The extruded view of the building storeys has shown in figure 3

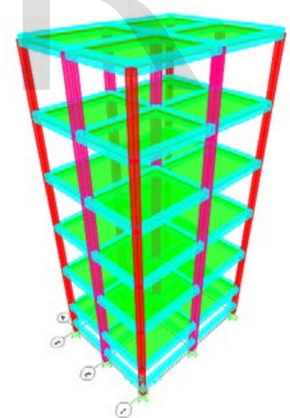

Fig.3 Model of the building

TABLE 2: Details of TMD for the building

Mass ratio	Column size (mm)		Beam size (mm)	
	C1	C2	B1	B2
0.02	66x120	85.7x140	100x140	120x150
0.03	96.6x130	88x120	140x200	160x200
0.05	94x160	100x180	180x200	160x200

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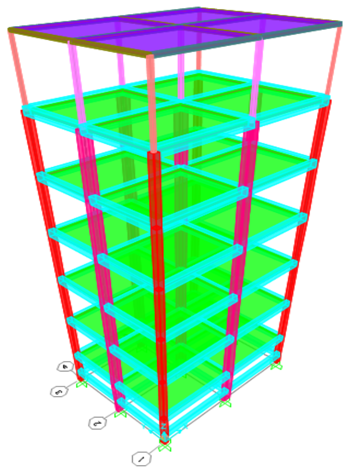

Fig.4 TMD in the form of soft storey placed at the top of the building

After analyzing the structure for three different earthquakes of different magnitudes, the values of the maximum displacements at the top of the building are obtained and are tabulated in table 3

TABLE3: Displacement at the top of the building

Time History	Maximum Displacement at the top of the building			
	Without TMD	2% TMD	3% TMD	5% TMD
Bhuj EQ	0.524	0.512	0.394	0.473
Uttarkashi EQ	1.055	0.901	1.05	1.125

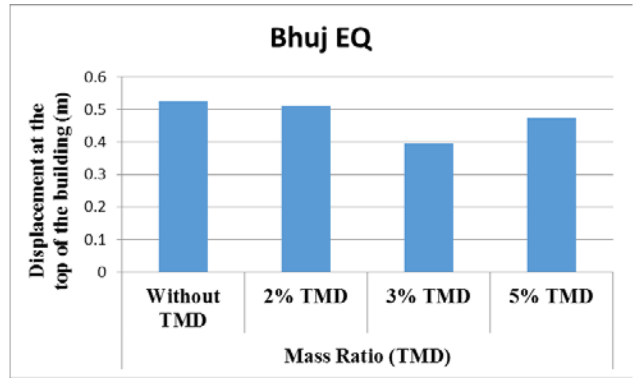

Fig.5 Displacement at the top of the building (Bhuj EQ)

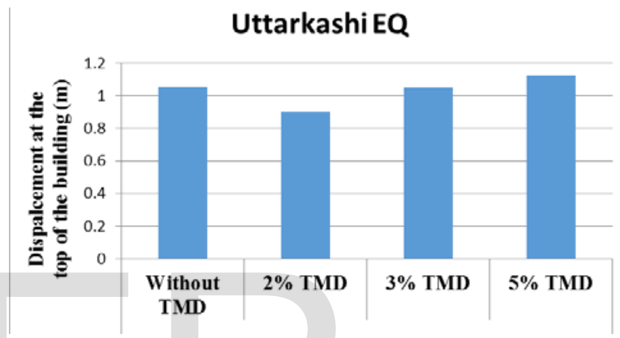

Fig.6 Displacement at the top of the building (Uttarkhashi EQ)

From the above results we can observe that, as the intensity of earthquakes or frequency of the building differs, the effectiveness of the mass ratio of Tuned Mass Damper changes. So in order to find out the effective mass ratio which gives the least displacement of the building, the responses of the building subjected to 25 earthquake data having different magnitude, frequency content and magnitude is compared and results.are.discussed.

TABLE 4: Displacement at the top of the building for the 25 EQ

SL No	Earthquake	Station	Displacement (mm)			
			WITHOUT TMD	2% TMD	3% TMD	5% TMD
1	Imperial Valley	El Centro Array # 4	18.76	16.25	24.25	20.85
2		El Centro Array # 5	38.32	35.44	33.38	33.32
3		El Centro Array # 8	30.93	38.94	34.69	39.44
4		El Centro Diff Array	130.2	78.09	45.82	64.66
5		Holtville Post Office	68.44	75	78.09	78.3
6	Loma Prieta	Gilroy Array # 3	11.98	17.37	24.9	29.99
7		Gilroy Array # 4	18.84	16.97	17.91	21.8
8		LGPC	367.1	264.5	197.8	238.7
9		Saratoga - Aloha Ave	90.17	90.74	88	112.4

10		Saratoga - W Valley Coll.	108.4	96.45	91	118.3
11	Cape Mendocino	Cape Mendocino	209.9	184.3	163.9	167.1
12		Eureka - Myrtle & West	35.04	23.64	27.36	31.62
13		Fortuna - Fortuna Blvd	44.41	46.21	40.4	51.54
14		Petrolia	257.3	185.8	142.2	147.6
15		Shelter Cove	8.69	6.73	5.87	5.62
16	Landers	Cool Water	73.74	86	55.37	51.61
17		Desert Hot Spring	36.22	38.1	43.37	56.72
18		Joshua Tree	125.5	129.9	95.88	113.3
19		Morongo Valley Fire Stn	96.84	68.76	60.28	71.68
20		Yermo Fire Stn	86.41	76.92	96.23	115.3
21	North Ridge	Arleta Fire Stn	132.2	120	99.29	125.5
22		New Hall - Fire Stn	139	169.1	172.6	163.9
23		New Hall - W Pico	391.9	373.6	350.2	437.4
24		Rinaldi Station	86.06	73.67	61.2	65.86
25		Saticoy Station	155.8	197.3	193.1	212.8

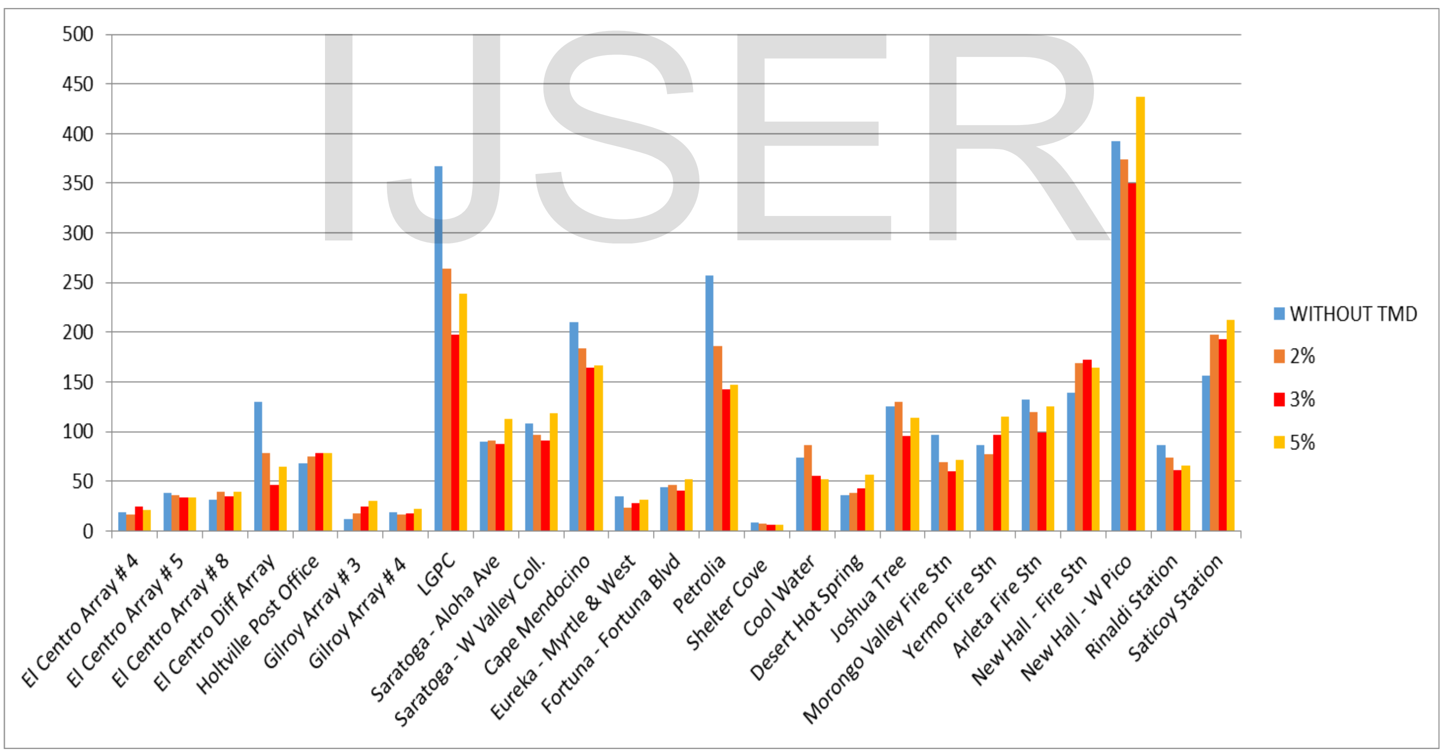

Fig.7 Displacement at the top of the building

The mean displacements at the top of the building are calculated and are tabulated below.

TABLE 5: Mean displacement at the top of the building

Mean Displacement at the top of the building			
Without TMD	**2% TMD**	**3% TMD**	**5% TMD**
110.486	100.39	89.7236	103.012

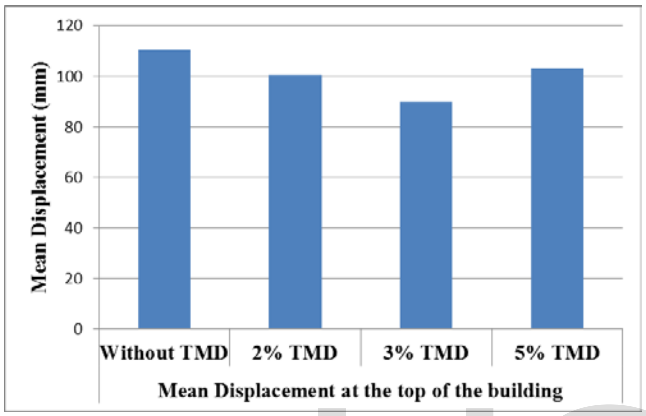

Fig.8 Mean displacement at the top of the building

5 CONCLUSION

After the analysis of rectangular building with and without Tuned Mass Damper, the following conclusions can be drawn:

- It has been found that the TMDs can be successfully used to control vibration of the structure.
- In general, a soft storey at the top of building reduces deflection at top building by about 10 to 25%
- Among the 2%, 3%, 4% and 5% TMD's, the effectiveness varies according to the earthquake ground motion data, and 3% TMD is found to be the most effective among all on a statistical basis.

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