A Study on Tuned Mass Dampers on 10 Storey RC Framed Structures Using SAP-2000 Software

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Abstract: The present pattern toward structures of perpetually expanding statures and the utilization of light weight, high quality materials, and propelled development strategies have prompted progressively adaptable and delicately damped structures. Presently a days a few strategies are accessible to minimize the vibration of the structure, out of the alternatives accessible for vibration control of which tuned mass dampers (TMD) is a never one .This study must be made to decide the viability of utilizing TMD for controlling vibration structure. The present study uncovers the impact of TMD with ideal parameters (frequency proportion and mass proportion). Here TMD is utilized as weak story which is thought to be comprised of RCC developed up to top of the building. A multi-story RC outline structure of 10 story with and without TMD has been considered for the analysis.3D models and examination will be done by utilizing a FE package SAP2000 by utilizing direct combination technique. TMDs with various mass proportions 2%, 3% and 4% are considered. The model was utilized to speak to structures situated in zone 5 of India. The systemic parameters examined are base shear, lateral displacement and storey drift. The structural parameters examined are axial shear, bending moment and shear force. Time history investigation has been considered out the structures must be subjected to a ground movement Bhuj for the working with, without TMDs and TMD as soft-storey and the outcomes are deciphered.

Keywords: TMD, FE, SAP, Soft-storey, Time history.

I. INTRODUCTION

A. General

Vibration control is a set of technical means aimed to reduce the undesired vibrations in a structure. The number of tall buildings being built is increasing day by day. Today we can't have a check of number of low-ascent or medium ascent and elevated structures existing on the world. For the most part these structures are having low natural damping. So expanding damping limit of a basic framework, or considering the requirement for other mechanical intends to expand the damping limit of a building, has turned out to be progressively normal in the new era of tall and super tall structures. Be that as it may, it ought to be made a normal outline practice to plan the damping limit into an auxiliary framework while planning the basic framework. The control of basic vibrations delivered by quake or wind should be possible by different means, for example, adjusting rigidities, masses, damping, or shape, and by giving uninvolved or dynamic counter strengths. The determination of a specific kind of vibration control gadget is administered by various components which incorporate efficiency, compactness and weight, capital cost, operating cost, maintenance requirements and safety. Vibration control of structures like tall buildings subjected to earthquake and wind excitations are important for human comfort and structural safety. Generally tall structures do not have sufficient damping; therefore control of the vibration response of the structures is very essential. Passive control devices like Tuned Mass Dampers (TMD) are elegant solutions for increasing damping in a structure, thereby, reducing the response due to external loading.

B. Tuned Mass Damper

Tuned mass damper is a passive control device which is mounted in the structures to reduce the amplitude of the vibrations or decreases the amplitude of the vibration. The vibration is produced from the earthquake forces, wind force and mechanical forces.

Applications

- They can minimize the vibration of the building against the earthquake forces and wind forces.

- They can prevent the discomfort, damage or outright structural failure.
- They are frequently used in automobiles and power transmission and buildings

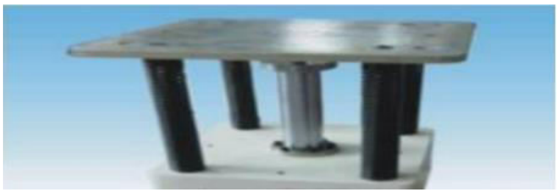

Figure 1.1: Tuned Mass Damper Description (Courtesy, suis 2011)

C. Mechanism of Tuned Mass Dampers

Tuned mass damper (TMDs) comprises of a mass, a spring, and a damper, which is joined to the other side of the working to control the reactions in two headings, TMDs might be put in two bearings on the highest point of a building. Besides, by putting the TMDs unconventionally, the torsional reaction of the building may likewise be controlled. The most imperative component of the TMDs is the tuning of frequencies, that is, the recurrence of the TMD is made equivalent to the basic recurrence of the structure. In view of different instabilities inborn in the properties of both the TMD and the structure, flawless tuning is exceptionally hard to accomplish. As a result, multi-tuned mass dampers (MTMDs) have been created for better tuning.

D. Soft Storey

A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storey's above. It is a multistore building which having more opening space. These floors especially dangerous against the earthquake forces, because of they cannot resist the lateral forces caused by swaying. Soft storey structures, having first stories a great deal less inflexible than the stories above are especially powerless to seismic tremor harm in view of extensive, unreinforced openings on their ground floors

II. SCOPE AND OBJECTIVES

A. Scope

The main focus of the present investigation is to evaluate the effect of seismic performance of a soft storey on top of a building and tuned mass damper on a reinforced concrete structure using non-linear time history analysis. Multi-storeyed building earthquake creates vibration on the ground that are translated into dynamic load which cause the ground and anything attached to it to vibrate in a complex manner it cause damage of structure. As result alternative strategies such as passive control devices are found to be effective reducing the seismic and other dynamic effect on a building. Hence it is necessary to analyses dynamic effect of building under TMD with different mass ratios.

B. Objectives

The present work focus on seismic performance on building with and without TMD and soft storey at top of a building .The building has a six bay (both in x and y direction) 10 storey building. a) To understand the concept of tuned mass damper (passive) in controlling vibration of a framed structures. b) To evaluate the response of multi-degree of freedom system (MDOF) frames structures with and without tuned mass damper by using SAP Software. c) To understand the dynamics of the frames structures subjected to earth quake load. d) To investigate the effect of the mass ratio of the TMD on the response of the structure subjected to a dynamic load excitation.

III. PRESENT STUDY

A. General

In the present study, the structure is modeled as a 3-dimensional frame using software package SAP2000 (version-14.2.4). This minimizes the numerical calculations and also verification of results. Non-Linear time history analysis can be performed on three dimensional structural models.

B. SAP2000 (Version-14.2.4) Software Package

SAP2000 (version-14.2.4) is a special purpose computer program. It is a versatile and user-friendly program that offers a wide scope of features like static and dynamic analysis, nonlinear dynamic analysis and nonlinear static pushover analysis, etc. It can perform pushover analysis for all types of structural models (Bare frame, Shear wall, RC Structure with Infill, RC Structure with Steel Bracing etc.). In general, the structural components of the model such as beams, columns are modelled as 3D frame elements, slab and other surface like wall, shear wall etc. are modelled as shell element which is generated as finite element model of slab and other surface entities.

C. Structural Parameters of the Building Data

Type of structure	OMRF
Material F_{ck} F_y	M25 and Fe 500
Type of structure use	Commercial use
column	0.230mx0.500m
Beam	0.230mx0.450m
Slab	0.150m
Poisson's ratio	0.02
Modulus of elasticity($5000x\sqrt{f_{ck}}$)	$25x\ 10^6$kN/m^2
Density concrete	25 kN/m^3
Density Cement mortar	20.45 kN/m^3
Density Brick	18 kN/m^3
Live load	4 kN/m^2
Wall load	10.56 kN/m^2
Floor finish	1 kN/m^2
Parapet load	6.2 kN/m^2
Floor finishing	1 kN/m^2

D. Earth Quake Parameters

Zone factor (Z)	V
Importance factor (I)	1.5
Response reduction factor (R)	3
Average response acceleration (S_a/g)	2.5

E. Modeling of Soft Storey at Top of the Building

Table 3.1: Dimension of the soft stories

Soft storey	Column sizes in mm	Beam sizes in mm	Slab thickness in mm
10 Storey	100x150	100x150	80

F. Plan and Elevation of the Model

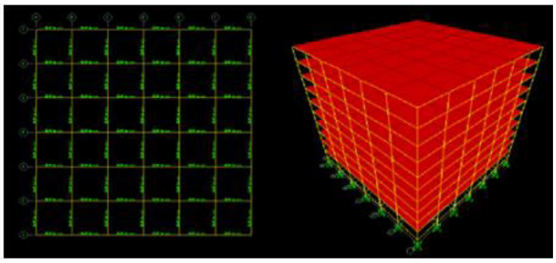

Figure 3.1: Plan and elevation of the 10 storey model

G. Modeling of Tuned Mass Damper

In present analysis a tuned mass damper model having mass ratio 2%, 3% and 4% is considered this type of model are used to resist the lateral load and vibration in a building these are generally attached at top of building.

1. Mass Ratio

μ = Md / M

Where Md = mass ratio of the damper

M = Total self-weight of the building

μ = Percentage

2. Frequency ratio

f = **1/ 1**+μ

*f*r = w**d /w**

Where fr =frequency ratio

wd =Fundamental frequency of damperw =modes in rad/sec

3. Effective damping ratio

ʕ = sqrt(**3**μ/ **8**(**1**+μ))

4. Effective damping

C = 2 ʕ Md Wd

Where Md = mass ratio of the damper

Wd =Fundamental frequency of damper

5. Stiffness of TUNED MASS DAMPER

Kd = Md X w^2d

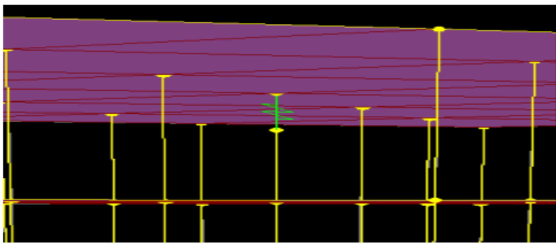

Figure 3.2: Tuned mass damper

H. Non Linear Time History Analysis

For time history analysis it is need to give the input data in terms of transient data. In SAP2000 the previous earthquake data recorded can be input in terms of acceleration (m/s2). For the present study the data taken is Bhuj Earthquake of January 26, 2001 at 08:46:42.9 I.S.T. Mag: 7.0 Mb, 7.6 Ms.

Station: Ahmadabad Lat & Long 23 02 N, 72E Comp: N 78 E

(i) Earthquake Detail Peak Ground Acceleration = 0.106g

Frequency = 3.65 Hz

Duration = 133.525 SecLocal magnitude = 7.6 Input Ground Acceleration = 0.1g.

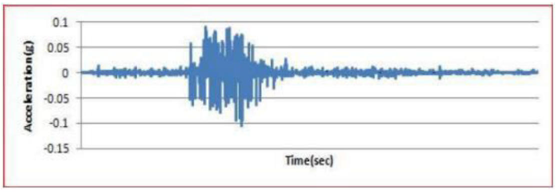

Figure 3.3: Input Time History Acceleration of a Bhuj Earthquake (0.1g)

IV. RESULT AND DISCUSSION

In the presence study a three dimensional six bay 5 m centre to centre both in x and y direction. A conventional RC framed structure, tuned mass damper (TMD of mass ratio 2%, 3% and 4%) and soft storey at the top of the building has been modelled for 10, 15, 20, 25 and 30 floors respectively with fixed base. The structure is assumed to be located in zone V of India and is subjected to time history analysis. The variation of systematic parameters like natural frequency, base shear, lateral displacement, story drift has been studied. The model has been subjected to Bhuj earth quake ground motion and the responses are interpreted.

A. Variation of Systematic Parameter

(i) Variation of Natural Frequency

Table 4.1: Variation of natural frequency for model 10 storey

Model 10 Storey	Frequency (Hz)			Percentage (%) of Variation
	Mode 1	Mode 2	Mode 3	
Fixed	0.48534	0.60191	0.64165	
Soft storey at top	0.45916	0.57117	0.60853	5.36
Mass ratio 2%	0.40860	0.50673	0.64165	15.87
Mass ratio 3%	0.38030	0.47191	0.64165	21.00
Mass ratio 4%	0.35674	0.44295	0.64165	26.49

From the above table it can be observed that there is a decrease of 5.36%, 15.87%, 21% and 26.49 in natural frequency for building with soft storey at top, TMD2%, TMD 3% and TMD 4% respectively when compared with fixed base.

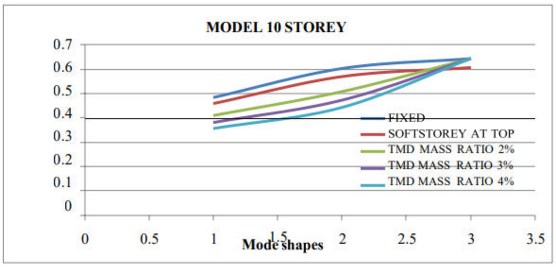

Figure 4.1: Effect of natural frequency on behaviour of mode shapes for 10 storey model

(ii) Variation of Base Shear

Table 4.2: Variation of base shear for model 10 storey

Model 10 storey	Base shear (kN)	Percentage(%) ofvariation
Fixed	3694.110	
Soft storey at top	3646.199	1.29
TMD Mass ratio 2%	3719.941	0.69
TMD Mass ratio 3%	3748.353	1.46
TMD Mass ratio 4%	3784.960	2.45

From the above table it can be observed that there is an increases of 1.29%, 0.699%, 1.46% and 2.45% in base shear for building with soft storey at top, TMD 2%, TMD 3% and TMD 4% respectively when compared with fixed base

(iii) Variation of Lateral Displacement

Table 4.3 Variation of lateral displacement for model 10 storey

Displacement (mm) 10 storey	Fixed	Tuned mass damper (TMD)			Soft storey at top
		2%	3%	4%	
Plinth	1.778	1.761	1.747	1.734	1.712
1	11.795	11.678	11.585	11.491	11.348
2	23.533	23.292	23.099	22.88	22.607
3	35.47	35.09	34.774	34.364	33.982
4	47.321	46.775	46.305	45.584	45.138
5	58.936	58.186	57.508	56.291	55.851
6	70.166	69.155	68.193	66.208	65.876
7	80.833	79.483	78.132	75.007	74.926
8	90.718	88.931	87.057	82.315	82.671
9	99.409	97.089	94.561	87.722	88.752
10	105.641	102.842	99.719	90.942	92.931

Table 4.4 Percentage variation of 10th floor is calculated for top storey, TMD with mass ratio 2%, 3%, and 4% compared with fixed base.

Percentage variation	Soft storey attop	TMD 2%	TMD 3%	TMD 4%
Decrease in percentage	12.03	2.64	5.39	12.04

From the above table it can be observed that there is a decrease of 12.03%, 2.64%, 5.39% and 12.04% in lateral displacement for building with soft storey at top, TMD 2%, TMD 3% and TMD 4% respectively when compared with fixed base.

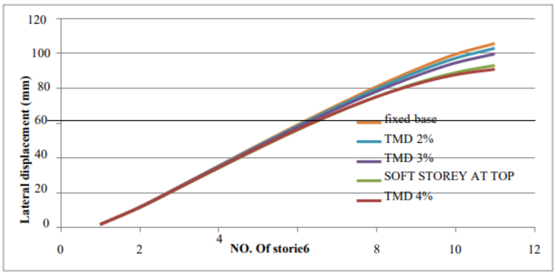

Figure 4.2: Effect of Lateral displacement for 10 storey model

(iv) Variation in Storey Drift

Table 4.4 Variation of storey drift for model 10 storey

10 storey in (m)	Fixed	TMD 2%	TMD 3%	TMD 4%	Soft storey at top
Plinth	0.006678	0.006424	0.006559	0.006505	0.006611
1	0.003913	0.003753	0.003838	0.003796	0.003871
2	0.003979	0.003792	0.003892	0.003828	0.003933
3	0.00395	0.003719	0.003844	0.00374	0.003895
4	0.003872	0.003571	0.003734	0.003569	0.003804
5	0.003743	0.003342	0.003562	0.003306	0.003656
6	0.003556	0.003017	0.003313	0.002933	0.003443
7	0.003295	0.002582	0.002975	0.002436	0.003149
8	0.002897	0.002027	0.002501	0.001802	0.002719
9	0.002077	0.001393	0.001719	0.001073	0.001918

Table 4.5 shows the Percentage variation of 10th floor is calculated for top storey, TMD with mass ratio 2, 3 and 4% compared with fixed base.

Percentagevariation	Soft storey attop	TMD 2%	TMD 3%	TMD 4%
Decrease in percentage	7.65	32.93	17.23	48.33

From the above table it can be observed that there is a decrease of 7.65%, 32.93%, 17.23% and 48.33% in storey drift for building with soft storey at top, TMD 2%, TMD 3% and TMD 4% respectively when compared with fixed base.

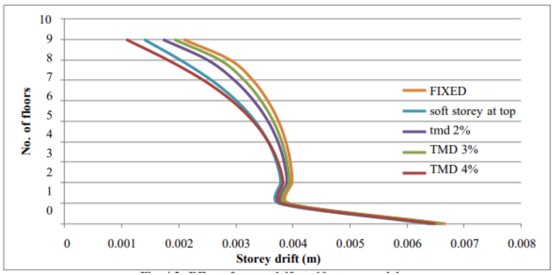

Figure 4.3: Effect of storey drift on 10 storey model

B. Effect of Ground Motion

The effect of tuned mass damper and soft storey at top on the building for the whole study is carried out for a single ground motion. The Bhuj earthquake with peak acceleration 0.106g is selected for the study using SAP software. The ground response analysis was carried out for fixed, with TMD and soft storey at top.

(i) Variation of Roof Displacement

Effect of variation of roof top displacement for building with TMD and soft storey at top studied compared with fixed base. The building models are subjected to Bhuj earthquake ground motion and the results are interpreted as shown in the below figure for 10 floor.

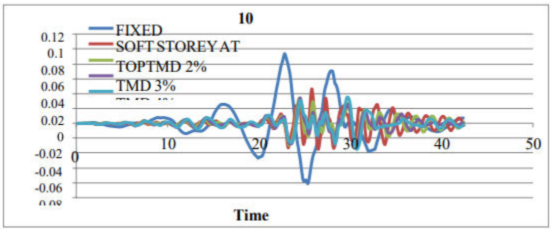

Figure 4.4: Variation of roof displacement for 10 storey model

(ii) Variation of Acceleration at Base

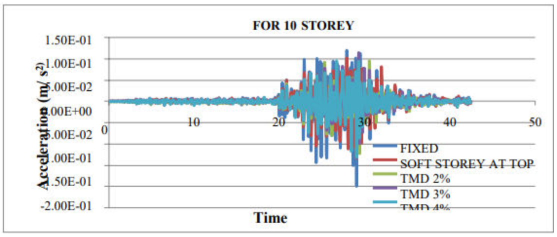

Figure 4.5: Effect of acceleration at base for 10 storey model

C. Variation of Structural Parameters

The variation of structural parameters like axial force, bending moment and shear force has been studied in our present study.

(i) Variation of Axial Force

Table 4.5 shows the variation of axial load for model 10 storey

10 storey	Axial load in kN
Fixed	2369.28
Soft storey at top	2426.04
TMD 2%	2329.58
TMD 3%	2315.6
TMD 4%	2303.17

From the above table it can be observed that there is a maximum axial load for building with soft storey at top and decreases with TMD 2%, TMD 3% and TMD 4% respectively when these compared with fixed base.

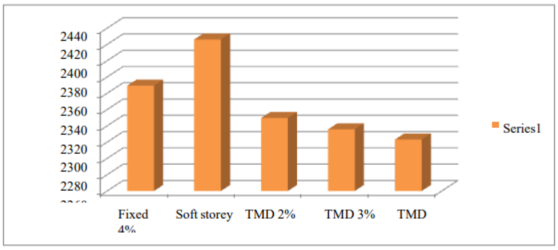

Figure 4.6 Variation of axial load for 10 storey model

(ii) Variation of Bending Moment

Table 4.6 shows the variation of bending moment for model 10 storey.

10 storey	Bending moment (kN-m)
Fixed	39.80
Soft storey at top	38.46
TMD 2%	40.32
TMD 3%	40.96
TMD 4%	41.79

From the above table it can be observed that there is a maximum bending moment at TMD 4%, TMD 3%, TMD 2% and minimum in soft storey at top when it is compared with fixed base.

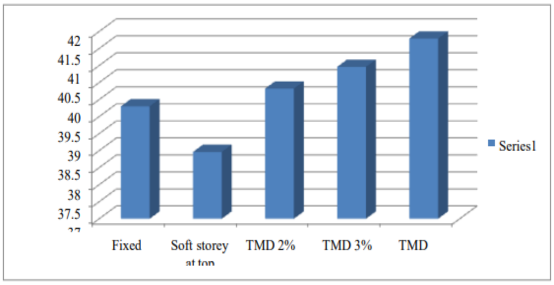

Figure 4.7: Variation of bending moment for 10 storey model

(iii) Variation of Shear Force

Table 4.7: shows the variation of shear force for model 10 storey.

10 storey	Shear force (kN)
Fixed	22.249
Soft storey at top	22.774
TMD 2%	22.048
TMD 3%	21.800
TMD 4%	21.474

From the above table it can be observed that there is a minor increase in shear force for building with soft storey at top, TMD 2%, TMD 3% and TMD 4% respectively when compared with fixed base.

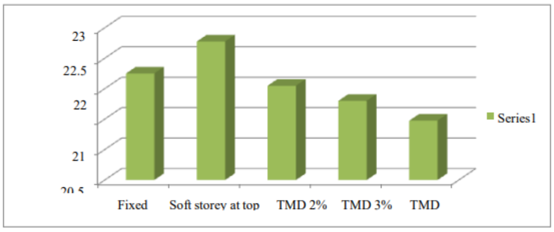

Figure 4.8: Variation of shear force for 10 storey model

V. CONCLUSIONS

This study presents summary of the project work for conventional RC framed structures with, without tuned mass damper and soft storey at top of building for 10 floors) in the seismic zone v, the effect of lateral load and time history analysis (Bhuj earthquake) has been studied .On the basis these results obtained, some of the important conclusions are presented here.

- The natural frequency decreases with the installation of TMD and soft storey at top of building when compared to conventional RC framed structures. Hence the structure will response less against lateral load (resonance effect will become list) in case of building with TMDs.

- Base shear decreases with increase in mass and stiffness building hence structure with TMD has baser shear and soft storey at top of building has less base shear when compared with conventional RC framed structures.
- The storey drift decreases with increase in mass and stiffness building.
- TMD with mass ratio 4% has more potential to reduce roof top displacement than TMD with mass ratio 2%, 3% and soft storey building when compared with conventional RC framed structure.
- TMD with mass ratio 4% has more potential to reduce base acceleration than TMD with mass ratio 2%, 3% and soft storey building when compared with conventional RC framed structure.
- Column axial force decreases with installation of TMDs and there is a slight increase in axial force for soft storey at top of building when compared with conventional RC framed structure.
- Beam bending moment increases with installation of TMDs and there is a slight decreases in bending moment for soft storey at top of building when compared with conventional RC framed structure.
- Beam shear force decreases with installation of TMDs and there is a slight increase in shear force for soft storey at top of building when compared with conventional RC framed structure.
- Tuned mass damper in form of soft storey at top of the building is found to be effective reducing seismic response of a building.
- Among 2%, 3% and 4% mass ratio, TMD with 4% is found better in reducing systematic and structural parameters.
- Soft storey presence also reduces seismic forces so it is found to be economical than installing a TMD which is uneconomical (price wise).

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