EFFECT OF TUNE MASS DAMPERS FOR RESPONSE CONTROL AND TIME HISTOREY ANALYSIS OF MULTI STOREY BUILDING

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ABSTRACT- *The behavior of structures in recent years indicates that moderate and severe earthquakes lead to substantial damages, extensively higher than what is expected. One solution in order to reduce the seismic response of the structures, especially in relative story displacements is usage of tuned mass dampers (TMD). In this study, comparisons between uncontrolled and controlled cases have been evaluated. This study was made to study the effectiveness of using TMD for controlling vibration of structure. At first a numerical algorithm was developed to investigate the response of a shear building fitted with a TMD. Then another numerical algorithm was developed to investigate the response of a 2D frame model fitted with a TMD. A total of three loading conditions were applied at the base of the structure. First one was a sinusoidal loading, the second one was corresponding to compatible time history as per spectra of IS-1894 (Part -1):2002 for 5% damping at rocky soil with (PGA = 1g) and the third one was 1940 El Centro Earthquake record with (PGA =0.313g).From the study it was found that, TMD can be effectively used for vibration control of structures. TMD was more effective when damping ratio of the structure is less. Gradually increasing the mass ratio of the TMD results in gradual decrement in the displacement response of the structure.*

***Key Words*: Tuned Mass Damper (TMD), Sinusoidal Loading, EI Centro earthquake, Mass ratio, Damping ratio, PGA, Time History Analysis (THA),**

1. INTRODUCTION

A tuned mass damper (TMD) is a passive control device consisting of a mass, a spring, and a damper that is attached to a structure in order to reduce the dynamic response of the structure. Energy is dissipated by the damper inertia force acting on the structure. It has been widely used for vibration control in many mechanical engineering systems. Recently many theories have been adopted to reduce vibration in civil engineering structures because of its easy and simple mechanism. *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. The mass is usually attached to the building via a spring-dashpot system and energy is dissipated by the dashpot as relative motion develops between the mass and structure.*

1.1 PASSIVE ENERGY DISSIPATION

Passive energy dissipation systems utilize a number of materials and devices for enhancing damping, stiffness and strength, and can be used both for natural hazard mitigation and for rehabilitation of aging or damaged structures. In recent years, efforts have been undertaken to develop the concept of energy dissipation or supplemental damping into a workable technology and a number of these devices have been installed in structures throughout the world (Soong and Constantinou 1994; Soong and Dargush 1997). In general, they are characterized by the capability to enhance energy dissipation in the structural systems in which they are installed. This may be achieved either by conversion of kinetic energy to heat, or by transferring of energy among vibrating modes. The first method includes devices that operate on principles such as frictional sliding, yielding of metals, phase transformation in metals, deformation of viscoelastic solids or fluids, and fluid orifice the later method includes supplemental oscillators, which act as dynamic vibration absorber.

1.1 TUNE MASS DAMPER

The concept of the tuned mass damper (TMD) dates back to the 1940s (Den Hartog 1947). It consists of a secondary mass with properly tuned spring and damping elements, providing a frequency-dependent hysteresis that increases damping in the primary structure. The success of such a system in reducing wind-excited structural vibrations is now well established. Recently, numerical and experimental studies have been carried out on the effectiveness of TMDs in reducing seismic response of structures (for instance, Villaverde(1994))

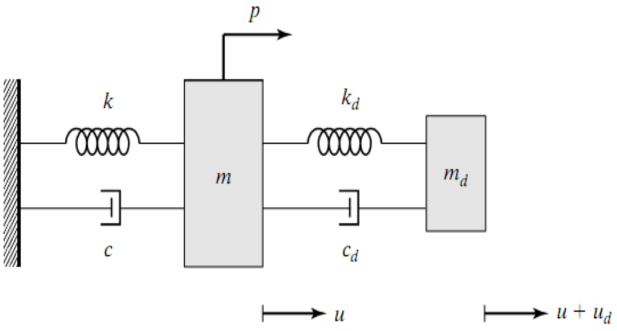


Fig1.1-Tune mass damper (Spring-dashpot system)

2. CLASSIFICATION OF CONTROL METHOD

2.1) ACTIVE CONROL

An active control system is one in which an external power source the control actuators are used that apply forces to the structure in a prescribed manner. These forces can be used to both or dissipate energy from the structure. In an active feedback control system, the signals sent to the control actuators are a function of the response of the system measured with physical sensors (optical, mechanical, electrical, chemical, and so on).

2.2) PASSIVE CONTROL

A passive control system does not require an external power source. Passive control devices impart forces that are developed in response to the motion of the structure. Total energy (structure plus passive device) cannot increase, hence inherently stable.

2.3) HYBRID CONTROL

The term "hybrid control" implies the combined use of active and passive control systems. For example, a structure equipped with distributed viscoelastic damping supplemented with an active mass damper near the top of the structure, or a base isolated structure with actuators actively controlled to enhance performance.

3. TIME HISTORY ANALYSIS

The time history analysis technique represents the most sophisticated method of dynamicanalysisforbuildings [4]. In this method, the mathematical model of building is subjected to accelerations from earthquake records that represent the expected earthquake at the base of the structure. This method consist of a step-by-step direct integration over a time interval the equation of motion are solved with the displacements, velocities and accelerations of the previous step serving as initial function.

4. AIM AND SCOPE OF WORK

- The aim of the present work is to study the effect of TMD on the dynamic response of multi- store frame structures under earthquake excitations
- . The scope of the work includes the modeling the multi-story building as 1D and 2D models. The finite elements have been used to discretize the building frame structures and TMD.
- The New mark Beta method is used to solve the dynamic equations for the structure-TMD system.
- *To review the literature, covering various types of tuned mass damper systems and the behavior of structures constructed with tuned mass damper.*
- *To develop a simplified model of a multistory building with identical parameters and simultaneously providing it without and with tuned mass damper.*

4. PROBLEM STATEMENT

A multi- story plane frame having story of height ‗H‘ and bays of length ‗L‘ is analysis. The 2D frame model is discretized into a number of elements, we can consider infinite numbers of nodes in each element such that inc = number of intermediate nodes per each column, inb = number of intermediate nodes per beam. Three degrees of freedom i.e, two translations and one rotation are associated with each node.

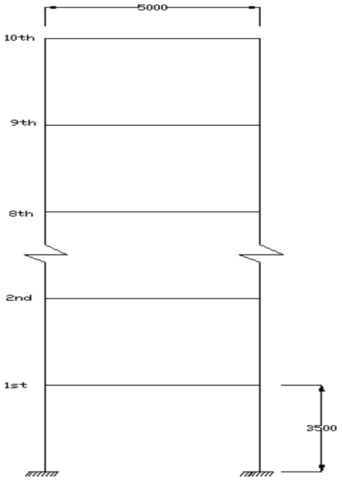


Fig 5.(a) Elevation of 2D plane frame structure

The following data are taken for analysis of the above frame:

Type of the structure -Multi-story rigid jointed plane frame.

- *Size of column -0.250 m 0.450m*
- *Size of beams- 0.250m 0.400m*
- *Depth of slab- 0.100m*

***Preliminary Calculations**:*

- *MOI of Column=* $0.25\ 0.45^3/12 = 1.9 \times 10^{-3}\ m^4$
- *MOI of Beam=* $0.25 \times 0.4^3/12 = 1.33 \times 10^{-3}\ m^4$

Loading on column and beam per unit length

- *Self -weight of column=.25x0.45x25x1000=2812.5N*

- *Self-weight of beam=0.25 x 0.4 x 25 x 1000 N=2500N*
- *Weight of slab=0.1 x 5 25 x 1000 N=12500*
- *live load on slab=5 x3.5 x1000 =17500N*
- *Total weight per meter length of beam=2500+12500+17500=32500N*

5.1 Free vibration analysis of the multistory frame

Table1: Convergent study of natural Frequencies(no of story-5, no. of bay-1, height of storey-3.5m)

Modes	*Natural frequencies in(rad/sec)*				
	No of elements				
	30	45	60	75	90
1st	13.424	13.424	13.424	13.424	13.424
2nd	43.513	43.511	43.510	43.510	43.510
3rd	81.725	81.709	81.706	81.704	81.704
4th	126.600	126.545	126.532	126.527	126.525
5th	167.534	167.015	166.924	166.899	166.889

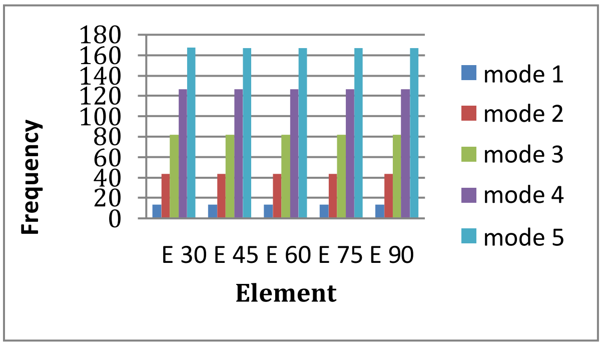


Fig-5.1.1: Convergent study of natural frequency

Table 2: *Variation of Natural frequencies with increase in number of story (No of Bay = 1,Height of each storey=3.5 m and Width of each Bay = 5 m) when inc=inb = 5*:

Modes	*Natural frequencies(rad/sec)*				
	No of story				
	1	*2*	*3*	*4*	*5*
1^{st}	*86.433*	*39.970*	*25.113*	*18.125*	*14.102*
2^{nd}	*230.385*	*135.935*	*85.117*	*59.917*	*45.708*
3^{rd}	*552.975*	*213.111*	*159.087*	*113.867*	*85.832*
4^{th}	*592.899*	*257.433*	*207.109*	*171.342*	*132.918*
5^{th}	*788.338*	*470.714*	*237.3117*	*196.733*	*175.321*

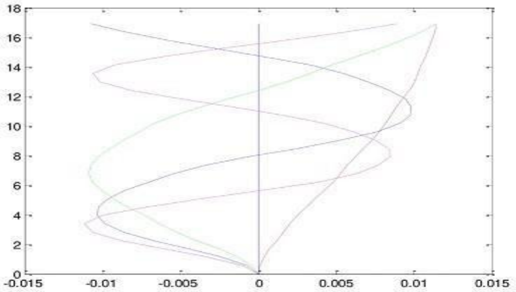


FIG-5.1.2 first four mode shape for framed structure

5.2) 2D MDOF frame model with TMD

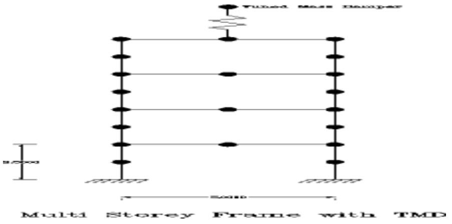


Fig. 5.2: Damper arrange with 2D frame

The TMD is placed at the 10th story and the 2D frame structure is subjected to both corresponding to compatible time history as per spectra of IS-1894(Part-1):2002 for 5 damping at rocky soil and 1940 El Centro earthquake load and the amplitudes of displacement is noted at the extreme right node of the 10th story with TMD and without TMD. The TMD is having mass ratio=0.1 and tuning ratio=1

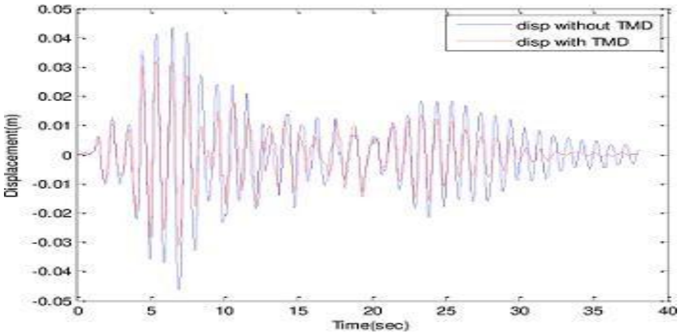


Fig 5.2.1) Amplitude of vibration at top story of 2D frame by placing TMD at top story when, corresponding to compatible time history as per spectra of IS-1894(Part- 1):2002 for 5 damping at rocky soil earthquake loading acting on the structure.

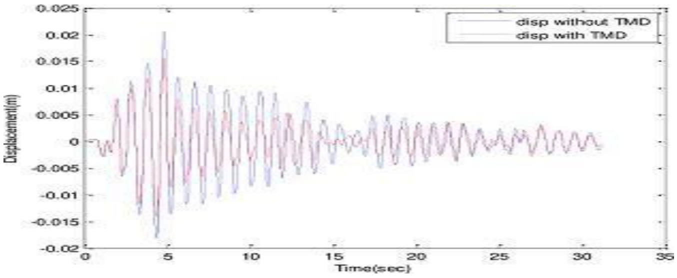


Fig 5.2.2) Amplitude of vibration at top story of 2D frame by placing TMD at top story when, El Centro(1940) earthquake loading acting on the structure.

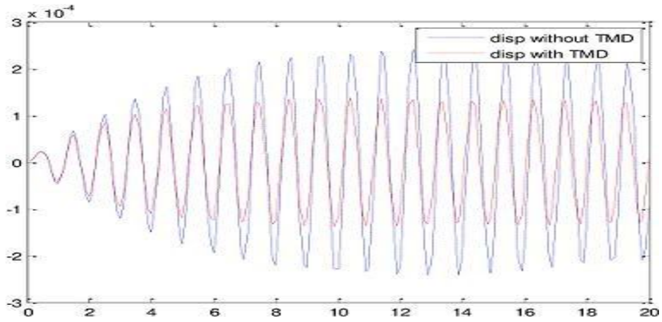


Fig 5.2.3) Amplitude of vibration at top story of 2D frame by placing TMD at top story when subjected to sinusoidal acceleration.

6. RESULTS AND DISCUSSION:

6.1) Damping Ratio: (Shear building)

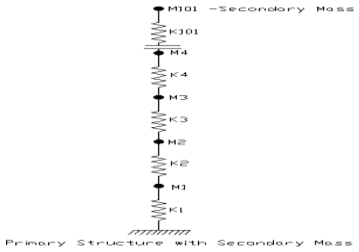


Fig 6.1 Damper-Structure Arrangement for shear building

6.1) Amplitude of vibration at top story by placing TMD at top story with variation of damping ratio of the structure when corresponding to compatible time history as per spectra of IS-1894(Part-1):2002 for 5 damping at rocky soil acting on the structure.

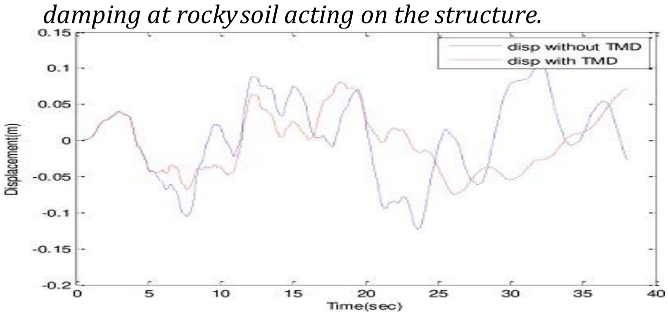


Fig 6.1 a) Response of the structure when damping ratio of the structure is 2

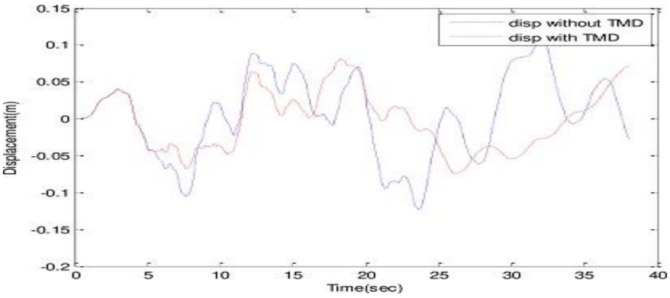
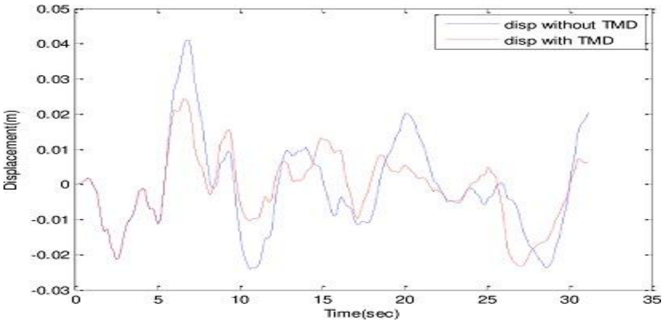


Fig 6.1b) Response of the structure when damping ratio of the structure is 5

Fig 6.1.1) Amplitude of vibration at top storey by placing TMD at top story with variation of damping ratio of the structure when, El Centro (1940) earthquake loading acting on the structure.



6 *Fig 6.1.1a) Response of the structure when damping ratio of the structure is 2*

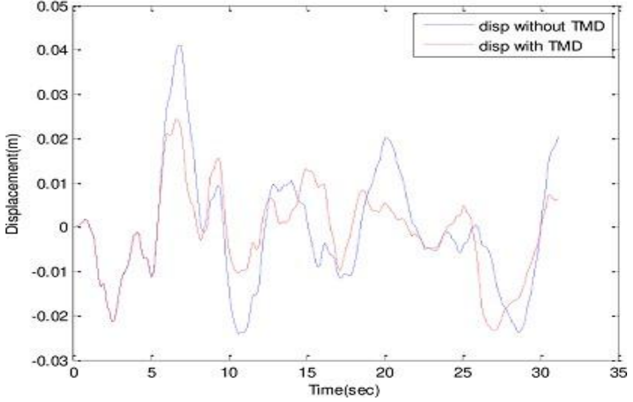


Table 6.1.1 b) *Response of the structure when damping ratio of the structure is 5*

RESULT-1. From the above figures it can be concluded that TMD is more effective in reducing the displacement responses of structures with low damping ratios (2). But, it is less effective for structures with high damping ratios(5).

6.2) Effect of TMD on structural damping *with variation of Mass ratio :*

A study has been carried out to see the effect of variation of mass ratio by keeping the damping of TMD and structure constant at 2 and considering three mass ratios and two earthquake-loads.

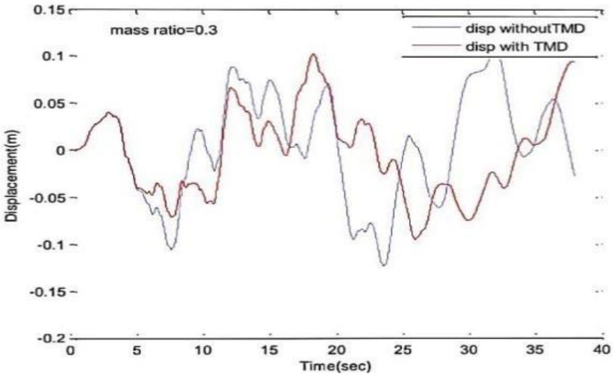
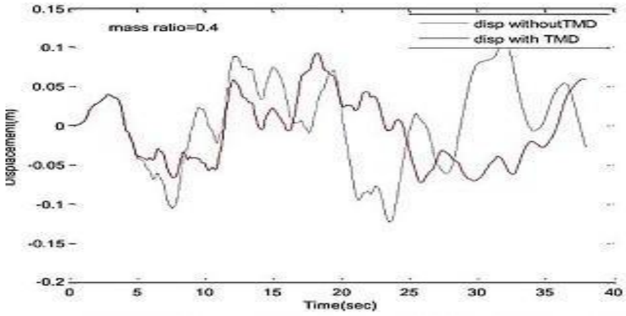


Fig. *6.2.a) Response of the structure with TMD with 0.3 mass ratio*



6.2.b): *Response of the structure with TMD with 0.4 mass ratio*

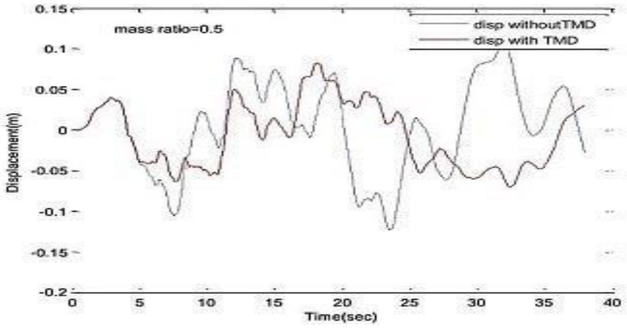


Fig6.2.c) Response of the structure with TMD with 0.5 mass ratio.

Fig 6.2.2 Amplitude of vibration at top story by placing TMD at top story with the variation of the mass ratio of the TMD when, El Centro(1940) earthquake EI loading acting on the structure.

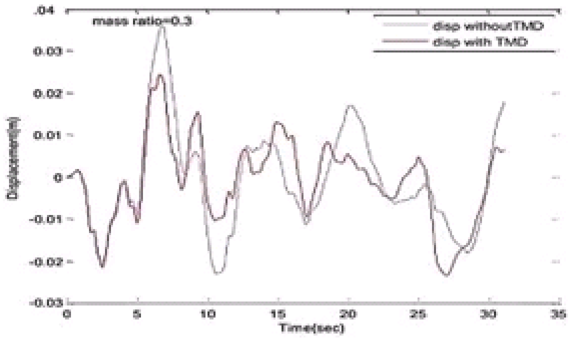


Fig 6.2.2 a) Response of the structure with TMD with 0.3 mass ratio

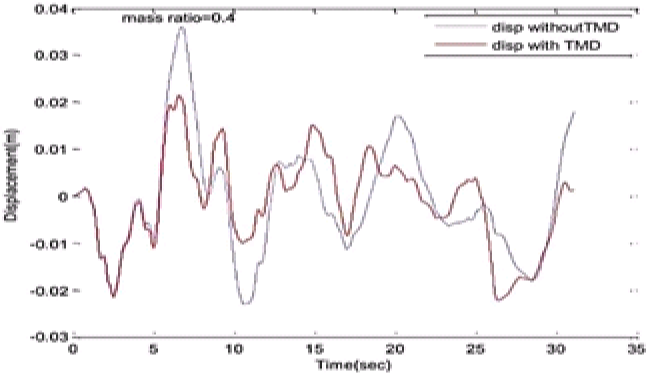


Fig 6.2.2 b) Response of the structure with TMD with 0.4 mass ratio

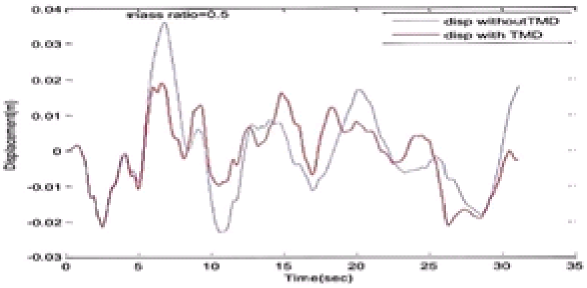


Fig 6.2.2 c) Response of the structure with TMD with 0.4 mass ratio.

RESULT-2 *It can be concluded from the above graphs that increasing the mass ratio of the TMD decreases the displacement response of the structure*

7. CONCLUSIONS

This study is made to study the effectiveness of using TMD for controlling vibration of structure. A numerical algorithm was developed to model the multistory multi-degree of freedom building frame structure as shear building with a TMD. Another numerical algorithm is also developed to analyses 2D-MDOF frame structure fitted with a TMD. A total of three loading conditions are applied at the base of the structure. First one is a sinusoidal loading and the second one corresponding to compatible time history as per spectra of IS-1894(Part -1):2002 for 5% damping at rocky soil and the third one is 1940 El Centro Earthquake record (PGA=0.313g).

Following conclusions can be made from this study:

- *It has been found that the TMD can be successfully used to control vibration of the structure:-.*
- *TMD is more effective in reducing the displacement responses of structures with low damping ratios (2). But, it is less effective for structures with high damping ratios (5).*

- *Applying the two earthquake loadings, first is the one corresponding to compatible time history as per spectra ofIS-1894(Part -1):2002 for 5% damping at rocky soil and second being the 1940 El Centro Earthquake it has been found that increasing the mass ratio of the TMD decreases the displacement response of the structure.*

8. REFERENCES

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