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CONTROL OF VIBRATIONS IN BUILDING DUE TO SEISMIC FORCE USING TUNED MASS DAMPER

Balachandar M
PG Student, Department of Civil Engineering, KL Deemed to be University,
Green Fields, Vaddeswaram, Guntur, Andhra Pradesh, India

Vinod Y
Assistant Professor, Department of Civil Engineering, KL Deemed to be University,
Green Fields, Vaddeswaram, Guntur, Andhra Pradesh, India

ABSTRACT

Now a days the construction is going with taller structures to provide more accommodation in less area due to an increase of population with the scarcity of land. These tall structures are constructed with flexible, low damping which causes major damage to the structure when the seismic force acts on the structure. The seismic waves caused by earthquake makes the structure to sway and oscillate in different directions. In order to reduce the vibrations of structure different approaches have been proposed, among them Tuned Mass Damper is preferable and have been widely used in practice. Analysis of a G+9 3D model with and without TMD using sap2000 software. The tuned mass damper is placed on top of the structure to observe the response of the structure with and without TMD.

Keywords: Mass Damper, Seismic Force, Building, Vibrations.

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1. INTRODUCTION

Right from the evaluation of the earth, the earth quake caused great disasters in the form of loss to property and human life .The seismic waves caused by an earth quake makes the structure to sway and oscillate in different directions depends on frequency, direction of ground motion, height of structure and type of construction. Most of the structures are designed to carry vertical load, so it may become weak during the time of earthquake. To keep the structure safely some control techniques are developed, such as passive control system, active control system and semi active control system. The passive control system does not require any power supply, the active control system requires an external power supply and works based on the sensors attached within the structure, the semi-active control system is a combination of both passive and active control system. The passive TMD is found to be a simple, effective, inexpensive and reliable means to suppress undesirable vibrations of structures.

The sap2000 is a finite element based structural program for the analysis and design of civil structures.Sap2000 has proven to be the most integrated, productive and general purpose structural program on the market today.Sap2000 is the easiest solution for our structural analysis and design purpose.

1.1. Tuned Mass Damper

The TMD is a passive device consisting of a mass, spring and a damper, which is attached to a structure to control the dynamic response of the structure. The TMD is designed to have the natural frequency tuned to that of the primary structure. When the particular frequency of the primary structure gets excited, the TMD will resonate out of phase with the structural motion and reduces its response. Mass of the secondary system varies between 1-10% of primary structure mass. The TMD's are generally installed at the top of a building and are tuned to first mode frequency of the building. The frequencies of both TMD and structure should nearly match, so that when the seismic force pushes the building, the TMD creates an opposite force, keeping its horizontal displacement zero or near zero. If the frequency of TMD is different from primary structure then the building motion would still be uncomfortable for occupants. The effectiveness of a TMD is dependent on the mass ratio, frequency ratio, and damping ratio.

2. OBJECTIVES

- Analysis of 10-storey 3D model by using SAP2000 software with and without TMD
- To find the Seismic response (displacement, acceleration and frequency) of a three dimensional building with and without TMD
- A Tuned Mass Damper is placed on its top through it to study its effects on displacement, acceleration and time period with and without TMD in SAP2000
- The result obtained from analysis of 10-storey building with and without TMD are compared with each other

3. MODELING

3.1. Base Model

A ten story building of height 30m with four bays in both x and y directions is chosen for the analysis. The bay width in both x and y directions is 6m and height of each floor is 3m. Various data regarding structure is given in Table 1.

Table 1 Preliminary assumed data

S.NO	Contents	Description
1	Floor to floor height	3 m
2	Slab thickness	0.135 m
3	Size of column	0.3m*0.25m
4	Size of beam	0.25m*0.25m
5	Seismic zone	4
6	Soil type	Medium
7	Frame type	SMRF
8	No of story	G+9

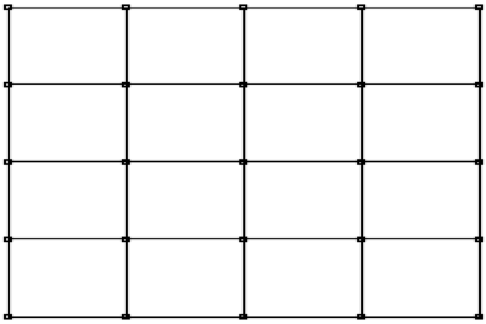


Figure (a) Plan

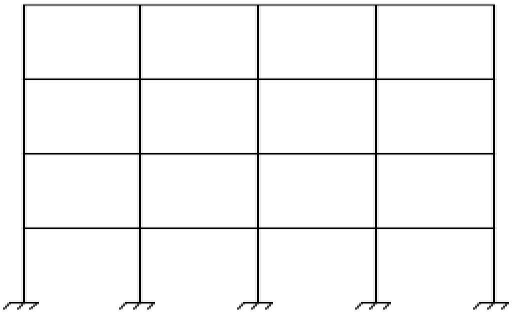


Figure (b) Elevation

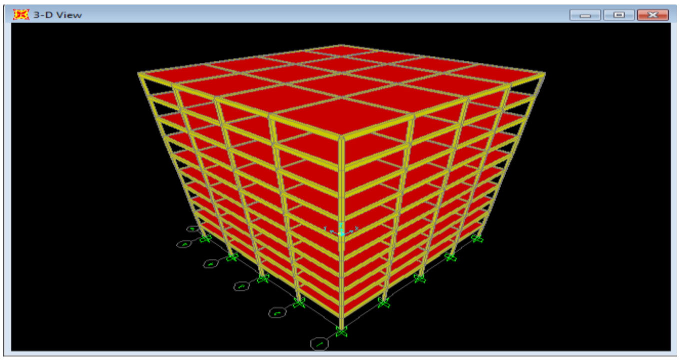


Figure (c) 3D view

3.2. Tuned Mass Damper

The TMD of three different mass ratios is to be attached to the above model to observe the seismic behavior of structure. Some of the details of tuned mass damper are given in Table 2.

Table 2 Details of the TMD

Content	9% mass of primary structure	6% mass of primary structure	3% mass of primary structure
Mass of the damper	86906 kg	57937kg	28968kg
Damping ratio	0.16	0.13	0.1
Effective stiffness in x-direction	7.5*10^7 kN/m	7.5*10^7 kN/m	7.5*10^7 kN/m
Effective stiffness in y,z directions	4262kN/m	2841kN/m	1420kN/m
Effective damping in the x-direction	25834kN-sec/m	18457kN-sec/m	9322kN-sec/m
Effective damping in y,z directions	641kN-sec/m	113kN-sec/m	40kN-sec/m

4. METHODOLOGY

In this paper linear dynamic analysis of G+9 building with and without TMD with a different mass ratios (3%, 6%, 9%) has been performed. Displacement, Acceleration and Frequency of structure with and without TMD are compared in this paper.

5. RESULTS

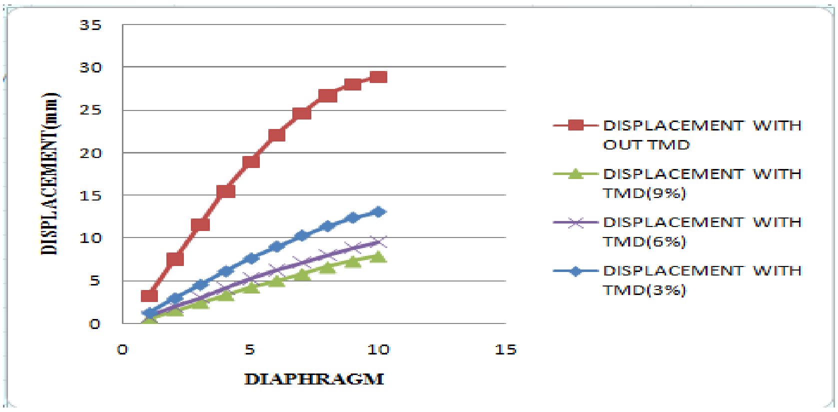
In the present study, a three dimensional 10 story is modeled in sap2000 with and without the TMD. A linear dynamic analysis is then performed on the same model for both the cases with changing mass ratios.

5.1. Displacement

Displacement is the movement of the structural element from its original position due to some external force. To keep the structure safely, the displacement caused by that force should be minimized by placing TMD. The displacement of the diaphragm of each floor with and without TMD has detailed in table 3 and graph 1

Table 3 Displacement at diaphragm of each floor with and without TMD

diaphragm	displacement without TMD (mm)	Displacement with TMD(mm)		
		3% mass ratio	6% mass ratio	9% mass ratio
1	3.2	1.2	0.8	0.6
2	7.5	2.9	1.9	1.5
3	11.6	4.5	3.0	2.4
4	15.5	6.1	4.1	3.3
5	19	7.6	5.2	4.2
6	22	9.0	6.2	5
7	24	10.3	7.1	5.8
8	26	11.4	8.0	6.6
9	28	12.4	8.8	7.3
10	28	13.1	9.5	7.9



Graph 1 Diaphragm versus Displacement

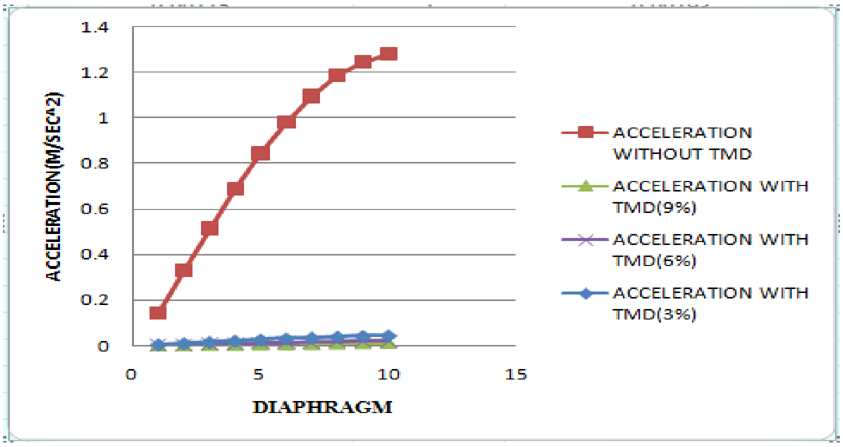
Graph 1 gives information about the comparison of displacement at diaphragm of each floor of structure with and without TMD. It is clear that the maximum displacement at the 10th diaphragm of structure in first mode without TMD is 28 mm. After providing TMD with different mass ratios (3%, 6%, and 9%) displacement at 10th diaphragm of structure in first mode is reduced to (13.1 m, 9.5 mm, 7.9 mm).

5.2. Acceleration

Acceleration is the change of velocity at joints of a structure due to the force acting on the structure. Acceleration at diaphragm of each floor with and without TMD has detailed in table 4 and graph 2.

Table 4 Acceleration at diaphragm of each floor with and without TMD

Diaphragm	Acceleration without TMD (m/sec^2)	Acceleration with TMD(m/sec^2)		
		3% mass ratio	6% mass ratio	9% mass ratio
1	0.145	0.004	0.001	0.001
2	0.333	0.009	0.004	0.002
3	0.516	0.015	0.007	0.004
4	0.688	0.020	0.009	0.005
5	0.845	0.026	0.011	0.007
6	0.982	0.030	0.014	0.008
7	1.097	0.035	0.016	0.009
8	1.185	0.039	0.018	0.011
9	1.247	0.042	0.020	0.012
10	1.280	0.044	0.021	0.013



Graph 2 Diaphragm versus acceleration

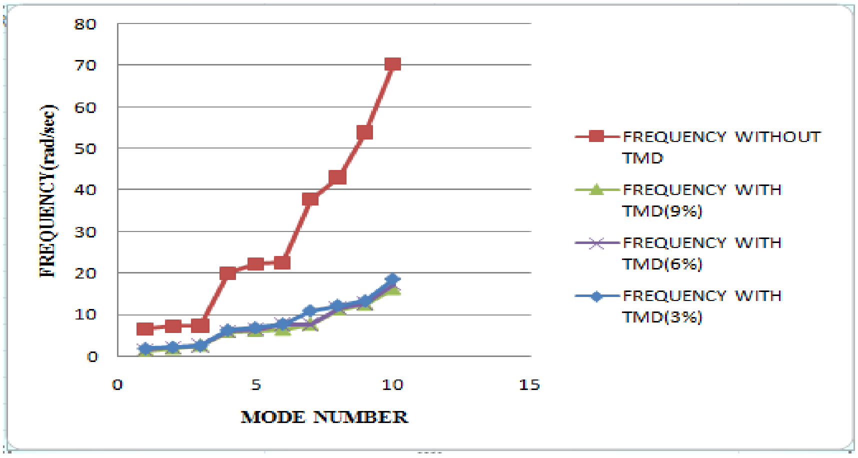
Graph 2 gives information about the comparison of acceleration at diaphragms of each floor of structure with and without TMD. The maximum acceleration at diaphragm 10 of structure in first mode without TMD is 1.28 m/sec^2.After providing TMD with different mass ratios(3%,6%,9%)the maximum acceleration at diaphragm 10 of structure in first mode is reduced to(0.04m/ sec^2,0.02m/ sec^2,0.01m/ sec^2) .

5.3. Frequency

The rate of oscillations occurred in one second, when the structure is vibrated due to external force is called frequency. Frequency is used to determine whether the structure is in flexible or rigid. If the oscillations are more then the structure easily tends to damage. The frequency of structure with and without TMD has detailed in table 5 and graph 3.

Table 5 Frequency of model with and without TMD

Mode Number	Frequency without TMD (rad/sec)	Frequency with TMD(rad/sec)		
		3% mass ratio	6% mass ratio	9% mass ratio
1	6.6	1.84	1.50	1.30
2	7.3	2.19	1.99	1.84
3	7.4	2.54	2.53	2.52
4	20.07	6.27	5.94	5.79
5	22.2	6.82	6.45	6.15
6	22.5	7.72	7.63	6.35
7	37.7	10.86	7.69	7.66
8	43.0	12.14	11.61	11.30
9	53.9	13.22	12.76	12.43
10	70.35	18.43	17.3	16.24



Graph 3 Mode number versus Frequency

Graph 3 gives information about the comparison of frequency of structure with and without TMD. It is clear that the frequency of structure in first mode without tuned mass damper is 6.6 rad/sec. After providing TMD with different mass ratios(3%,6%,9%) the frequency of the structure reduced to (1.84 rad/sec,1.5 rad/sec,1.3 rad/sec).

6. CONCLUSION

The behavior of 10 story building under linear dynamic analysis with and without TMD was analyzed in sap2000 software. TMD is more effective in controlling the displacement, acceleration, and frequency of structure under earthquake.

Table 6

Content	Top story displacement in the first mode(mm)	Acceleration in first mode(m/sec^2)	Frequency in first mode(rad/sec)
Normal building	28	1.28	6.6
TMD with 3%mass ratio	13	0.04	1.84
TMD with 6%mass ratio	9	0.02	1.50
TMD with 9%mass ratio	7	0.01	1.30

From the Table 6 it is clear that structure with TMD reduces the response of structure. Response is more reduced with TMD of a mass ratio (9%), because the mass of the TMD mainly effects the controlling of dynamic response.

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