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Seismic Vibration Control of Multi-Story Buildings using Tuned Mass Dampers

Shivam Kasana[1], Shilpa Pal[2] and Dipti Ranjan Sahoo[3]

[1,2]*Gautam Buddha University*
[3]*I.I.T. Delhi*
E-mail: [1]skasana94@gmail.com, [2]shilpa@gmail.com

Abstract—*The idea of smart city has been introduced to identify the broad area of activities to enhance the life quality of people. In any smart city, the buildings should be able to withstand the adverse effect of the earthquake tremors. The main focus of the present investigation is to evaluate effect of tuned mass dampers on the structural response of multi-story RC frame structures by performing nonlinear static analysis (push over analysis). Pushover analysis is a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations. In this study, a 5 story building is modeled in SAP 2000, the positions of plastic hinges are assigned manually to the building using moment-curvature curve. The systemic parameters studied are base shear, joint displacement and hinge formation. Based on the analysis results, it has been concluded that the effect of tuned mass dampers plays a significant role to decrease the base shear, joint displacement, bending moment and shear force in a multi-story RC framed Structure.*

1. INTRODUCTION

As the frequency of occurring earthquakes are increasing now a days, the need for vibration control of different structures are important for human comfort and structural safety. Assessing earthquake risk and improving engineering strategies to mitigate damage are thus the only viable options to create more resilient cities and communities.

A control system is generally a combination of the seismic isolation system and control devices, such as passive, active or semi-active control elements is often referred to as a hybrid control system [1]. Nowadays it is not easy to have a count of number of low rise or medium rise and high rise buildings existing in the world. The count of high rise buildings being built is increasing day by day.

The control of vibration response of tall structures is very essential because they do not have sufficient damping. Vibration control devices such as Tuned Mass Dampers (TMD) are smart solutions for increasing damping in a structure, thereby reducing the response due to external loading.

The simplified approaches for the seismic evaluation of structures, which is accounted for the inelastic behavior, generally use the results of static collapse analysis to define the inelastic performance of the structure. Currently, for this purpose, the nonlinear static procedure (NSP) or pushover analysis described in FEMA-273 documents are used. However, the procedure involves certain assumptions and simplifications that some amount of variation is always expected to exist in seismic demand prediction of pushover analysis.

In this paper, the comparisons of various parameters are done for a structure with TMD to a structure without TMD.

Tuned mass dampers

The concept of the tuned mass damper (TMD) dates back to the 1940s (Den Hartog 1947). It is made up of a secondary mass with properly tuned spring and damping elements, providing a frequency-dependent hysteresis that increases damping in the primary structure.

The inertial, resilient, and dissipative elements in these devices are mass, spring and dashpot (or material damping) for linear applications and their rotary counterparts in rotational applications.

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. MODELING

2.1 Base model

A five story building with three bays of total height 13.6 m, is chosen for the analysis. The dimension of the story is increased above ground floor from 1.2 m to 3.1 m. The bay width in x direction is 5 m and in y direction, middle bay is of 2 m and rest is 3 m. the various data regarding the structure is given in Table 1.

Table 1: Preliminary assumed data

S. No	Contents	Description
1.	Floor to floor ht.	3.1 m
2.	Plinth ht.	0.55 m
3.	Parapet ht.	1.5 m
4.	Slab thickness	150 mm
5.	External wall thickness	230 mm
6.	Internal wall thickness	150 mm
7.	Size of column	300 mm X 450 mm
8.	Size of beam	300 mm X 450 mm
9.	Seismic zone	IV
10.	Soil type	Medium
11.	Frame type	SMRF
12.	No. of story	G+4
13.	Imposed load on floor	3 kN/m^2
14.	Imposed load on roof	1.5 kN/m^2
15.	Density of concrete	25 kN/m^3
16.	Density of masonry wall	20 kN/m^3
17.	Importance factor	1
18.	Mass ratio of TMD	5%

With respect to the above structural data, the plan and elevation of the building is shown in Fig. 1 and 2.

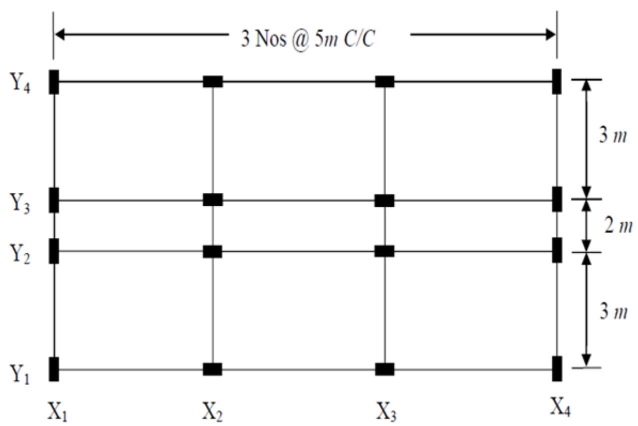

Fig. 2: Plan of the building

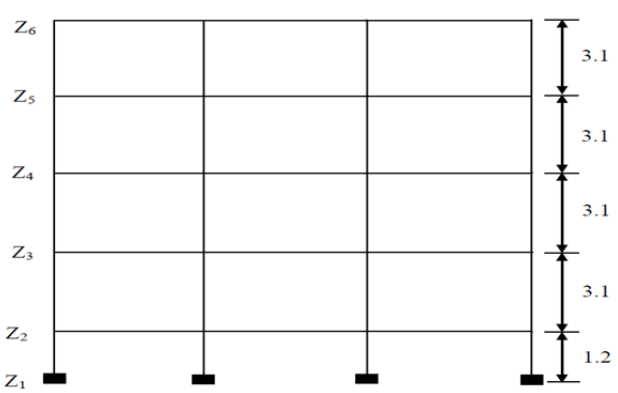

Fig. 2: Elevation of the building

The 3d view of the model is demonstrated by Fig. 3.

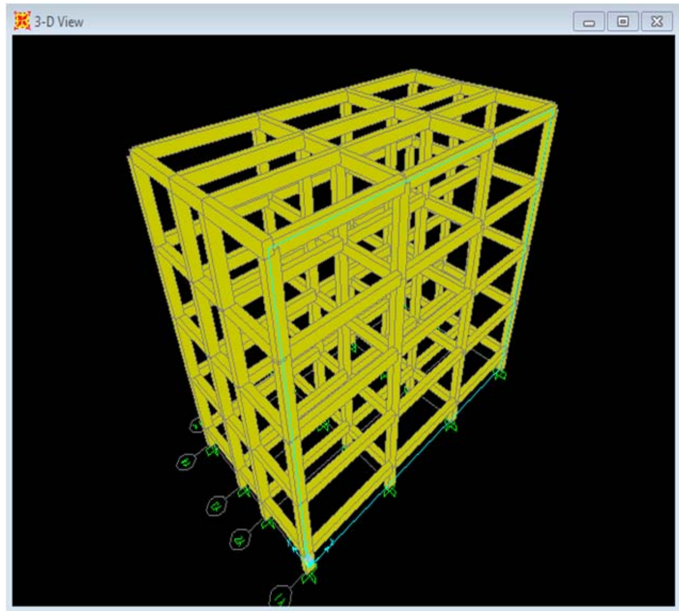

Fig. 3: 3D view of building

2.2 Moment Curvature Curve

Moment curvature curve of the cross section used in this study is shown in Fig. 4.

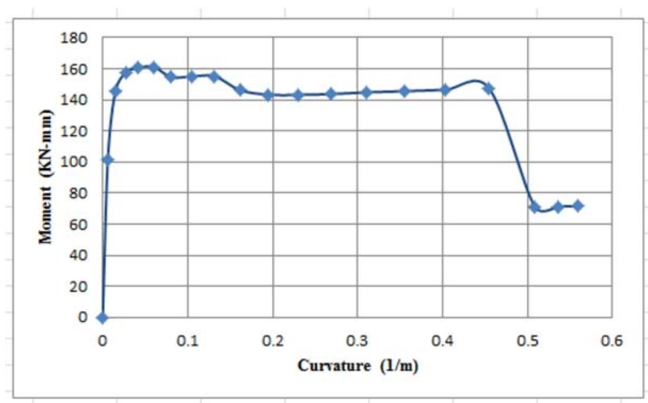

Fig. 4: Moment curvature curve

3. METHODOLOGY

In this paper nonlinear static analysis of a G+4 building attached with and without tuned mass damper of 5% mass ratio has been performed. The positions of plastic hinges are assigned manually using moment curvature curve.

4. RESULTS

In the present study a two dimensional five story RC framed building is modeled in SAP 2000, as per the data given, with fixed base, without and with tuned mass damper and of 0.05 mass ratio subjected to the dead and live loading and a displacement controlled pushover load case. Nonlinear static analysis is then performed over the same frame for both the cases.

4.1 Base Shear

Variation in base shears due to push over load case for 2D-RC frame without and with TMD of 5% mass ratio are studied. The values of base shear are given in the Table 2 below:

Table 2: Base shear results

S. No.	Case	Base Shear (kN)
1.	Without Damper	294.265
2.	With Damper	260.819

4.2 Push Over curve

Push over curve is the variation of base shear with respect to the displacement. In this, displacement is plotted on x axis and base shear is plotted on y axis. The values of base shear and displacement at different steps for both cases are shown in the table 3 and 4.

Table 2: Displacement vs base shear when damper is not used

Step no.	Without Damper	
	Displacement (m)	Base Shear (KN)
0	0.000055	0
1	-0.005548	74.67
2	-0.027642	227.84
3	-0.034442	253.772
4	-0.03975	262.238
5	-0.060909	279.744
6	-0.06472	281.811
7	-0.11472	290.761
8	-0.164093	299.557
9	-0.165774	299.726
10	-0.172082	299.692
11	-0.191766	297.032
12	-0.274477	244.771
13	-0.324477	208.389
14	-0.374477	172.007
15	-0.424477	135.625
16	-0.474477	99.243
17	-0.480543	94.83
18	-0.480543	94.83
19	-0.499945	80.657

Table 3: Displacement vs base shear values when damper is used

Step no.	With Damper	
	Displacement (m)	Base Shear (KN)
0	0.000068	0
1	-0.006429	68.231
2	-0.03236	203.066
3	-0.039599	223.733
4	-0.04086	225.703
5	-0.075811	244.872
6	-0.115104	253.874
7	-0.165104	259.04
8	-0.227382	264.398
9	-0.232378	264.489
10	-0.235161	264.389
11	-0.257492	261.685
12	-0.313095	241.767
13	-0.377349	215.446
14	-0.427349	182.484
15	-0.477349	149.521
16	-0.499932	134.633

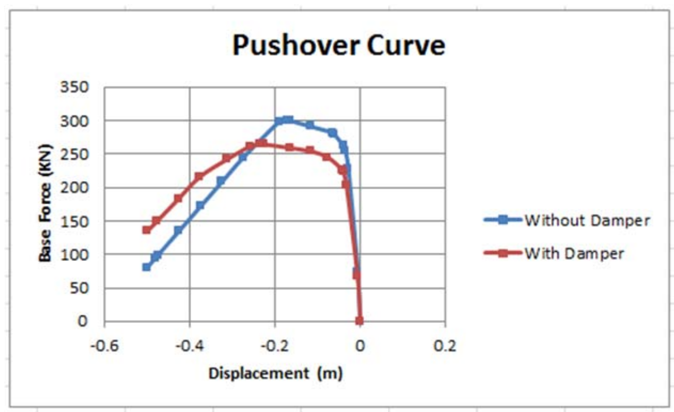

Fig. 5: Push over curve

4.3 Hinge Formation

When the tuned mass dampers are used in 2D RC frame, the performance of the structure is found to be better as compared to the structure without TMD. Most of the hinges formation occurs in beams which is a good sign for the performance of the building.

5. CONCLUSIONS

In this study, it is attempted to study the ability of TMD to reduce earthquake induced structural vibration. After the analysis of 2D RC frame with Tuned Mass Dampers and without any damping device, the following inferences are drawn:

1) TMDs can be successfully used to control vibration of the structure.
2) There is decrease in base shear when the tuned mass damper of 0.05 mass ratio is used in the structure.
3) Most of the hinge formation occurs in beams which is a good sign for the performance of the building.

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