Vibration Control of High -Rise Reinforced Concrete Building Due To Seismic Excitations by Using Tuned Mass Damper

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Abstract - *This case study includes the investigation of the mitigating effects of TMD on the response of this tall RC structure equipped with TMD is to be established using the software ETABS v.16. The behavior of this structure is now evaluated by conducting a detailed dynamic analysis. High rise RC structure under the action of (far fault) Seismic Events. Tuned Mass Damper (TMD) is a passive control device which absorbs energy & reduces response to imparted vibrations. Properly designed soft storeys can act as TMD. Here an analytical study is conducted on the effectiveness of soft storey as TMD to reduce translational structural vibrations .A ten storied irregular building from literature is considered for the case study. For in this study consider with two plan irregular conditions like L, C shapes with suitable mass ratio. Finite element model of this tall RC structure equipped with TMD is to be established using the software ETABS v.16. The behavior of this structure is now evaluated by conducting a non linear dynamic analysis, with the use of ALTADINA-1 ground motion data*

Key Words: mass ratio, mitigation, passive control device, soft storey, translational vibration

1. INTRODUCTION

In recent years, high rise buildings are very common and flexible with low damping capacity. Buildings are vibrated during seismic excitations become discomfort for peoples. So we can adopt different techniques for seismic mitigation. Dampers are one of the important methods for reduction of seismic excitations. From Recent studies, TMD is the good seismic effective damper used in high rise R.C structures. In the case of TMD attractive option is reducing excessive floor vibrations. TMD consists of a secondary mass with properly tuned spring and damping elements, providing a frequency-dependent hysteresis that increases damping in the primary structure. TMD is attached to a structure in order to reduce the dynamic response of the structure. 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 the structure. The selection of a TMD as vibration control device is governed by a number of factors which include efficiency, compactness and weight, capital cost, operating cost, maintenance requirements and safety. Mainly three types of TMD are there, pendulum, flexure, and spring tuned mass damper, shown in fig (1).

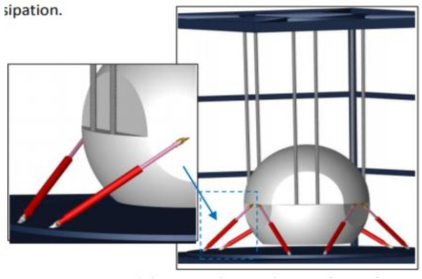


Fig -1: pendulum TMD

2. THEORETICAL BACKGROUND

In 1909 Frahm proposed the first concept of the TMD, to reduce the rolling motion of ships as well as ship hull vibrations. In 1928 Ormondroyd and Den Hartog presented a theory for the TMD with detailed discussion of optimal tuning and damping parameters. It is a device mounted in structures to prevent discomfort, damage, or outright structural failure caused by vibration. They are used for prevent failure of buildings during earthquakes in high rise buildings. They are also known as an active mass damper (AMD) or harmonic absorber. A tuned mass damper is a system for damping the amplitude in one oscillator by coupling it to a second oscillator. If tuned properly the maximum amplitude of the first oscillator in response to a periodic driver will be lowered and much of the vibration will be 'transferred' to the second oscillator. The concept of the tuned mass damper (TMD) applied in 1940s. Till date tuned mass damper have been installed in large number of structures all around the globe. The Centre point Tower in Sydney, Australia was the first tuned mass damper installation project. The success of such a system in reducing wind-excited structural vibrations is now well established. Recently, lot of numerical and experimental studies has been carried out about the effectiveness of TMDs in reducing seismic response of structures. It is attached to a vibrating structure to reduce undesirable vibrations. TMD are of different types like Pendulum TMD, Mass and coil TMD, Mass and flexure TMD. It can also be placed as a soft storey at top.

It consists of a mass (m), a spring (k), and a damping device (c), which dissipates the energy created by the motion of the mass .In the Fig 2,the damper consists of a mass M2 of a spring K2 of a damping C2. The value of M2 and K2 are chosen so that the moving part of the damper system can be tuned properly to the structure frequency. It consists of a secondary mass with properly tuned spring and damping elements, which is provided for a frequency-dependent hysteresis that increases damping in the primary structure.. Recently, numerical and experimental studies have been carried out on the effectiveness of TMDs in reducing seismic response of structures.

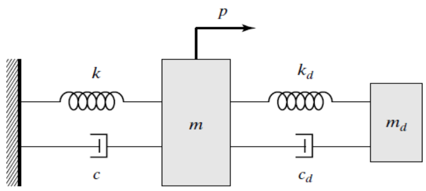


Fig -2: operation principle of TMD

3. NON-LINEAR TIME HISTORY ANALYSIS

Nonlinear dynamic analysis of structure is analysed under the ground excitation data of ALTADINA -1 earthquake (magnitude 7.1, total duration 12.113 sec) .It has a peak pounding acceleration of 0.319g at time 2.006 seconds. Damping of 3% is taken for earthquake ground motion. The graph of the function is illustrated in the Fig.3.

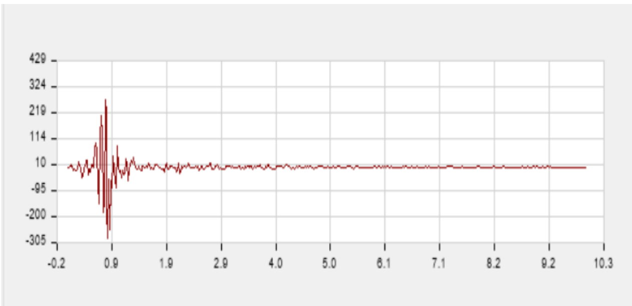


Fig -3: ALTADINA -1 earthquake data

4. IDENTIFICATION OF CASE STUDY STRUCTURE

The selected (G+10) RCC building is assumed to be located in zone V as per IS: 1893-2016. The top floor is made up of steel floor. The structure is of high importance due to its post-earthquake functional needs and therefore an importance factor of 1.5 is adopted.

Table -1: Details of building

Grade of concrete	M20
Grade of steel	Fe 415
Floor to floor height	3m
Plinth height	1m
Slab thickness	100
Column I	230X500 mm
Column II	400X400 mm
Beam	230X500mm
Grid spacing X	4m
Grid spacing Y	3m

5. INTRODUCING TUNED MASS DAMPER (TMD)

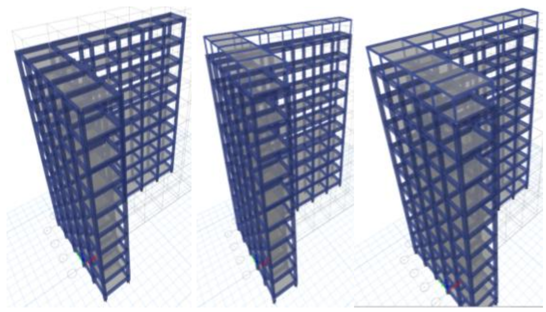
Soft storey TMDs are introduced at the top floor of all the plan irregular buildings as shown on fig 7.5. Properties of buildings are different, since it depends on mass ratio, frequency ratio and damping ratio. Properties of TMDs are given in the table 2.

Table -2: Properties of TMD

Total mass of building	7848.2974 KN	
Mass ratio	3%	5%
Mass of TMD	235.4489KN	392.4148KN
Stiffness of damper	636653.8256 N/m	1061089.808 N/m
Details of top storey	ISHB150,ISMB100	ISHB150,ISMB175
Damping ratio	0.3	0.3

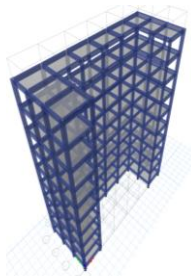
6. METHODOLOGY

A systematic study regarding the vibration control of high rise R C plan irregular building with the use of TMD. Mainly two plan irregular conditions are considered like L, C, is assumed to be located in zone IV in medium soil. For in these case 3 models are considered for all four conditions with suitable mass percentage like without TMD, 3% TMD, 5% TMD etc. All the buildings are analysed using ETABS v.16 and designed as per IS: 456:2000.They are subjected to gravity and dynamic loading. Beams and column members have been defined as 'frame elements' with the appropriate dimensions and reinforcement. All columns in the models are assumed to be fixed at the base for simplicity. 10 storey building is selected for these analysis. For the presence of TMD add a storey on top so became 11 storey building with suitable mass percentage conditions. The storey height of building is 3m , height of soft storey of building is 2m. The grade of concrete is M-20. For in these analysis top storey is considered as steel, ISHB 150 ,ISMB100,ISMB 175 are selected for top steel storey with the use of suitable TMD modeling. Shown in fig:4 and 5.

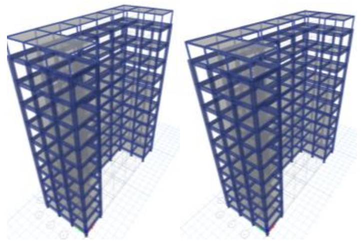


a) NO TMD b)3%TMD C)5%TMD

Fig -4: L-shape plan irregular building



a) NO TMD



b) 3% TMD c) 4% TMD

Fig -5: C-shape plan irregular building

7. RESULTS AND DISCUSSION

Dynamic responses of buildings such as Fundamental Time period, fundamental mode shapes, acceleration, displacement and story responses are given here under different cases. Modal analysis is carried out to obtain the mode shapes and fundamental time period of all buildings.

7.1 Time Period

Modal analysis is carried out to obtain the mode shapes and fundamental time period of buildings. Fundamental time period of four buildings for mode 1 are given in table 3.

Table -3: Fundamental time period of buildings

	Model	L-shape	C-shape
Fundamental time period (s)	No TMD	1.186	1.137
	3% TMD	1.241	1.188
	5% TMD	1.265	1.212

7.2 Accelaration

Time history analysis is carried out with ALTADINA-1 earthquake data to obtain joint acceleration of four plan irregular conditions with suitable mass %. Shown in table 4. Mass % vs acceleration characters are shown in figure 6 and 7.

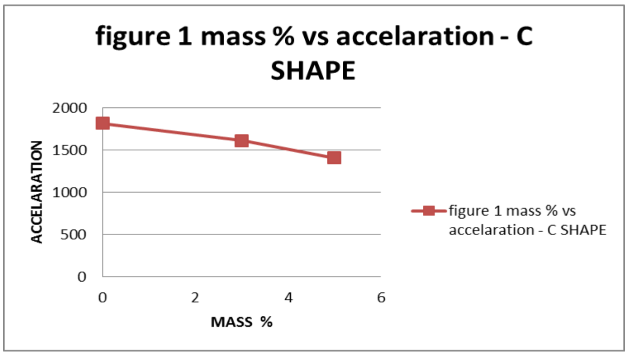


Chart -1: mass % vs acceleration -Cshape

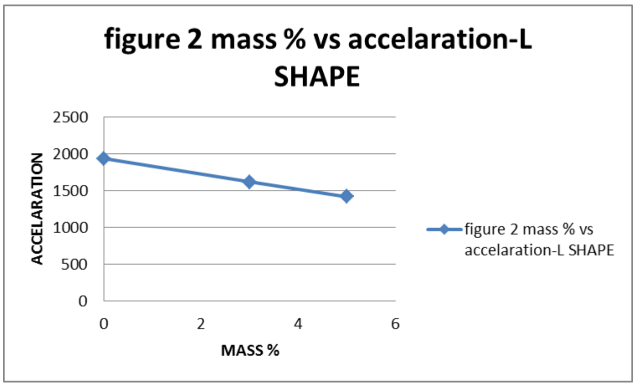


Chart -1: mass % vs acceleration –Cshape

Table -4: Accelaration results of buildings

IRREGULAR PLAN	MODEL	ACCELARATION (mm/s²)
C –SHAPE	No TMD	1817.800
	3% TMD	1609.780
	5% TMD	1406.160
L–SHAPE	No TMD	1936.880
	3% TMD	1615.370
	5% TMD	1420.180

8 CONCLUSIONS

- Displacement, acceleration, base shear, storey drift are more without the presence of TMD.
- By placing TMD at top of the buildings, displacement, acceleration, base shear, storey drift are reduced. TMDs are more effective in mitigating vibrations.
- Compared with acceleration results 36.38% decrease in L-shape building. So in this category L-shape building is perfect.

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