TUNED MASS DAMPER IN MULTISTOREY BUILDING FOR STRUCTURAL STABILITY

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Abstract: **Tuned mass dampers (TMDs) are control devices consisting of a mass-spring-dashpot system connected to the structure in a way to vibrate out of phase with the main structure, if tuned to the appropriated frequency. In this way the energy is transferred to the TMD reducing amplitude vibration on the main system. A 10 storeyed building was used for the analysis. Varying the parameter value position and number of TMDs were used to fixing the optimum requirements. The analysis was done by varying the mass ratio 2%, 4%, 6% and 8% at centroid, front and left corners of the top storey. To find optimum number of TMD, analysis was carried out by using up to 3 numbers of dampers, each at last storeys. 2% mass ratio of one damper at front corner of top storey is sufficient for this analysis. Numerical modelling of the structure with TMD installed is performed using the finite element ANSYS computational package.**

Keywords: **ANSYS Software, Acceleration, Base Shear, Deformation, Equivalent Stress, Optimum mass ratio, Optimum location, Storey Displacement, Tuned Mass Damper.**

I. INTRODUCTION

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). Tuned mass dampers (TMDs) are passive control devices that are generally installed at the tops of buildings to control the responses of buildings produced due to wind or an earthquake. Tuned mass damper is also known as a harmonic absorber, their application can prevent discomfort, damage, or outright structural failure. They are frequently used in power transmission, automobiles, and buildings. TMD have been successfully implemented to control the responses of some well-known towers (buildings) produced by winds, such as Citicorp Tower, Sydney Tower, and so on.

The objectives of the study are to analyse a multi storey building to obtain the response of the structure, to find the optimum size of Tuned Mass Damper, to find the optimum position at where energy dissipation can be effective.

II. LITERATURE REVIEW

From the numerical simulations performed by **Jorge Eliécer Campuzano Carmona, Graciela N. Doz, Suzana Moreira Avila(2010)** the optimal calibration parameters TMD were found. These experimental tests will prove the performance of TMD in reducing vibrations in floors.

The vibration control performance of a tuned mass damper was conducted by **Zheng Lu, Dianchao Wang, and PeizhenLi(2014)**. Increasing the mass ratio can generally improve the control effects; at the tuning frequency, the damping effects are remarkable.

According to the study, conducted by **Mr. Ashish A. Mohite, Prof. G.R. Patil (2015)** on ‘Earthquake Analysis of Tall Building with Tuned Mass Damper’ TMD is effective in reducing displacement and acceleration and, thereby, can be used for structures under earthquake.

From the study on ‘Vibration Control of a Frames Structure Using Tuned Mass Damper’ by

Haruna Ibrahim, Daha S. Aliyu, Hafizu Hamza(2015) Tuned mass damper are designed to reduce wind responses on tall buildings, this study is made to study the effectiveness of using tuned mass damper for controlling vibration of structure due to excitation force (wind). It also observed that the displacement response is decreased by increasing damping ratio of TMD.

III. MODELLING AND ANALYSIS

A. Free Vibrational Analysis:

A rectangular shaped 10 storeyed building is considered for the project work. It consists of 20 columns, 31 beams and 12 slabs in each floor. It has a dimension of 20m X 13.5m in plan.

Size of the column = 600mm × 600mm

Size of the beam = 300mm × 600mm

Slab thickness = 150mm

Number of storey = 10

Height of storey = 3m

Each slab consists of 5m × 4.5m.

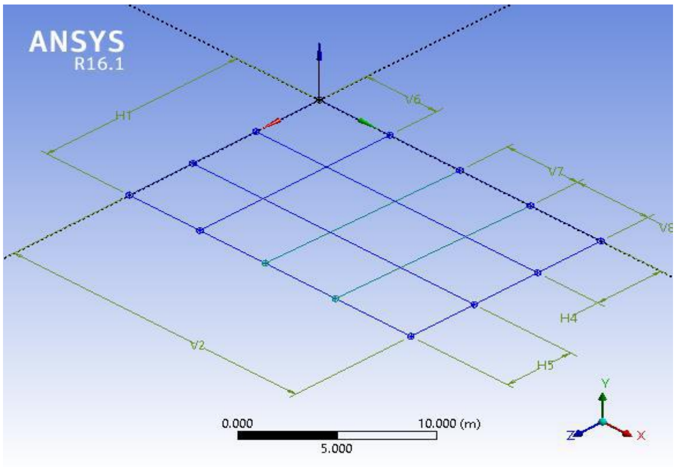

Fig 1: Plan of the Building

Mass of the building = 2.1276×10^6kg

Volume of the building = 8.865×10^{11}mm^3

Natural frequency of the building = 6.748rad/s

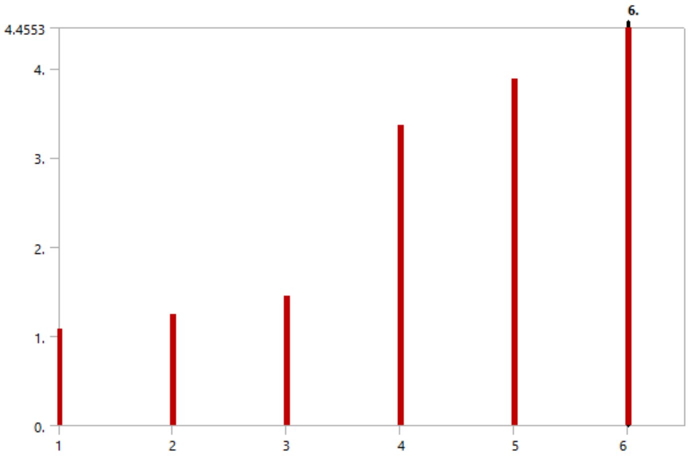

Fig 2: Frequency at each Mode

B. Forced Vibrational Analysis:

El Centro earthquake values were used to find the response of multi-storey building. Ground acceleration of 2927.2mm/s2 for 30 sec was applied in X direction to the building. Initially the building without TMD was analysed. After that. placed the TMD at centre of the top storey. 2%, 4%, 6% and 8% mass ratios were used for the analysis.

After fixing the mass ratio optimum location of TMD was obtained. For that, analysis of the building carried out by placing damper at centre, front and left corners of the top storey. Since the building is symmetric about the axes front and back corner will give same result as well as left and right corner give same result.

Finally optimum number of TMD is to be calculated. For that initial analysis was done by placing TMD at top storey only. After that TMD placed at last two stories. At last 3stories were placed with TMDs.

IV. RESULTS AND DISCUSSION

In order to find the optimum mass ratio of TMD 2%, 4%, 6% and 8%s of ratios were used. The damper is designed with appropriate mass, spring stiffness and damping ratios, and it attached to the top storey.

TABLE I: OPTIMUM MASS RATIO

Mass ratio	2%	4%	6%	8%	Without TMD
Mass(kg)	42552	85104	127656	170208	-
Stiffness(N/m)	1937626.77	3875253.5	5812880.3	7750507	-
Damping Ratio	0.14	0.196	0.242	0.277	-
Equivalent Stress(MPa)	1.537	6.935	9.6058	14.028	24.798
Deformation (mm)	17.013	27.833	38.684	54.25	62.09
Acceleration (mm/s^2)	141.04	256.34	332.24	608.57	462.31
Storey Displacement (mm)	15.54	25.201	35..28	49.92	61.9
Base Shear (N)	6.78×10^5	1.1×10^6	1.53×10^6	2.24×10^6	4.2665×10^6

In order to find the effect of damping ratio on the response of the structure different mass ratios were analysed. Since damping ratio is increases with mass ratio. 2% mass ratio is sufficient for the TMD to reduce the earthquake effect on the structure.

After fixing the mass ratio of building, optimum position of TMD was obtained. In order to find optimum position, place the TMD at the centre of the top slab. Then it placed at left corner and front corner of the floor and the results were listed in table.

TABLE II: OPTIMUM LOCATION OF TMD

Position of TMD	**Centroid**	**Left Corner**	**Front Corner**
Equivalent Stress (MPa)	1.533	4.58	8.13
Deformation (mm)	17.013	16.557	17.271
Acceleration (mm/s^2)	141.04	226.74	119.03
Storey Displacement (mm)	15.54	16.19	13.58
Base Shear (N)	6.78×10^5	7.33×10^5	6.25×10^5

In the case of Acceleration it's value become less at the front position than centroid and left corner. Storey Displacement and Base Shear also reduces while placing at the front corner. It is better to place the TMD of mass ratio of 2% at front or back corner of the building.

After fixing the mass ratio and location, number of dampers required for effectiveness can be found out. It can be done by placing dampers at 9thfloor, 8thfloor along with last storey. One, two and three dampers were used for the analysis. Initially place the damper at the top storey and results were obtained. After that place dampers at last and second last storey and placed dampers at top three storeys and analysis were done.

TABLE III: NUMBER OF TMD

No. of Dampers	**1**	**2**	**3**
Mass of each Damper (kg)	42552	21276	14184
Stiffness (N/m)	1937626.77	3875253.4	5812880.31
Damping ratio	0.14	0.14	0.14
Equivalent Stress (MPa)	8.13	3.883	36.36

Deformation (mm)	17.271	34.08	21180
Acceleration (mm/s^2)	119.03	825.11	1464.7
Storey Displacement (mm)	13.58	33.925	193.08
Base Shear (N)	6.25×10^5	6×10^5	8.23×10^6

While placing two numbers of dampers Equivalent stress and Base shear of the building were decreases. Whereas deformation, Acceleration and Storey Displacement were increases. In the case of three dampers all parameters were increases drastically.

V. CONCLUSIONS

A 10 storeyed building was used to find the effect of TMD in earthquake analysis. El Centro earthquake accelerations were used for the analysis. Optimum parameters of TMD along with position and number of TMD were find out using ANSYS software. From the analysis following conclusions can be recorded.

- It has been found that the TMDs can be successfully used to control vibration of the structure.
- Using TMD of 2% mass ratio significantly reduces Equivalent Stress, Deformation, Acceleration, Storey Displacement and Base Shear of the structure.
- Increasing the mass ratio decreases the response. This is expected since increasing mass ratio results in a higher TMD damping ratio, and consequently a higher damping in the mode of vibration.
- As damping ratio increases it affect the structure inversely.
- While placing the TMD at the front or rear side of the top most storey can reduces the earthquake response of the structure than placing at centre of the building.
- Tuned mass damper (TMDs) consists of a mass, a spring, and a damper, which is attached to one side of the building to control the responses in two directions. Furthermore, by placing the TMDs eccentrically, the torsional response of the building may also be controlled.
- For an aesthetic appearance, the TMD can be placed at the rear side of the building.
- Since it is a 10 storeyed building one damper at topmost storey is sufficient for resisting the earthquake effects.
- From analysis it can be seen that it is necessary to properly implement and construct a damper in any high rise building situated in earthquake prone areas.

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