Structural Behaviour of G+6 Building with Weak Storey on Top as Tuned Mass Damper

Vanishri A. Patil, Deepa A. Joshi

Abstract: Due to fast urbanization along with horizontal devlopment, devlopment in the vertical direction is also the need era. Safety of these structures is of utmost importance. Several techniques are available to provide saftey against these seismic forces. Out of the various techniques, one is "Tuned Mass Damper". TMD is an energy absorbing device that is installed in a structure. A lot of studies has have been carried and it has been proved that TMD as a device works effectively. The current study aims to develop a TMD as a storey at the top instead of a device. A storey is provided at the top of the structure which will be acting as TMD. The mass of the top structure is to be kept varying from 3% to 5%of the entire mass of the structure with the same frequency.

Keywords: TMD, Tuned mass damper, mass ratio.

I. INTRODUCTION

Earthquake forces are generated in structure by earthquake-induced ground motion. This makes earthquake action fundamentally different from any other imposed load. Thus earthquake forces are directly influenced by the dynamic characteristics of the building and inelastic characteristics of the structure itself. The important dynamic characteristics of the building are its natural period or frequency of vibration. The natural time period is the rate at which structure moves back and forth if they are given a horizontal push. For controlling the seismic response or vibratory response of the structure subjected to earthquake excitation TMD can indeed be used as an energy-absorbing device.

The concept of tuned mass damper (TMD) as an added energy-absorbing system is one of the available methods of structural control. The active tuned mass damper is an excellent technique in protecting buildings and their contents from large environmental loads. A simple form of Tuned Mass Damper is suggested for moderately high multistoried buildings. This TMD is in the form of an additional storey at the top of the building. In this study, this additional storey is designed in such a way that its natural frequency will match with that of the building. Here another factor which is to be kept in mind is that the weight of the additional storey mass should be about 3 to 5% of the total weight of building for this condition to satisfy, the beam and column of this additional storey will be smaller in size than that of the building. The height of the weak storey is kept the same as that of another storey. These stories are analyzed to obtain the natural frequency, axial force, moment & shear.

For years, extensive research has been done to study the structural response of structure subject to lateral loads. The TMD concept was first applied by Frahm in **1997**. The overall objective of the paper was to determine the optimum parameters of TMD that result in a considerable reduction in the response to earthquake loading. The results indicated that the proposed TMD parameter reduces the displacement and acceleration response significantly (up to 50%).

Jagadish et. Al. (1979), Kaynia et. Al.(1981), Sladek and Klinger (1983) have studied the effect of the tuned mass damper on the seismic response of the structure. Further Villeaverde (1985) and Koyama (1993) [3] presented a detailed analysis of the effectiveness of TMD. They considered structure and TMD as multi-degree of freedom system and performed Eigenvalue analysis. Based on this analysis they showed that for TMD to be effective, its natural frequency should be equal to that of structure and TMD should be heavily damped.

II. METHODOLOGY

The present work aims at the study of the effect of the provision of storey at the top of the structure as a tuned mass damper. A rectangular shape structure with an increase in storey height also with varying mass ratios is considered for sofware analysis.

Fahim Sadek et. al. [5] formulated optimum parameters of TMD for SDOF and MDOF systems. By using the formulas given by Fahim Sadek et. al optimum parameters of TMD can be obtained, which results in a considerable reduction in response to earthquake loading

G + 6 structures with 5 bay in the X direction and 4 bays in the Y direction are considered with L/B ratio 1.25. Floor Height is considered as 3m, Bay length considered 5m, Mass Ratios considered are 3, 3.5, 4, 4.5, 5. Weight is assigned which covers a dead load of beams, columns, slab, and walls. The floor finish is assigned as 1kN/m2, Live load is considered as 3kN/m2 and seismic load parameters are considered.

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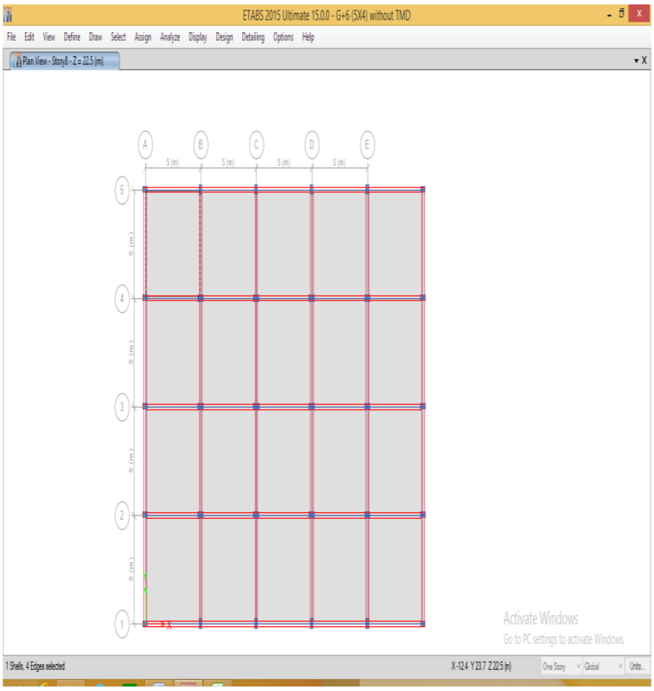

Figure No 1. A Plan of a G+ 6 structure 5 x 4 bay

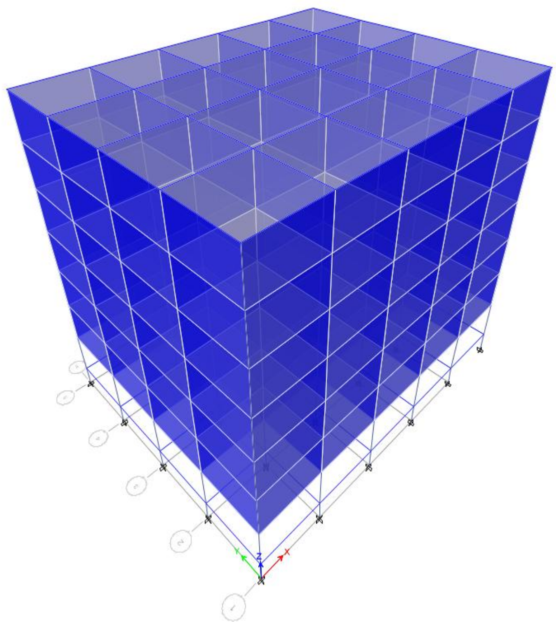

Figure No 1 B. 3D view of 5 X 4 bay 4 storey's

The sizes of column and beam for rectangular building of G + 6 structures are mentioned in Table no 1 and Table no 2

Table No 1 Column size details of structure without TMD

Label used in software	Group Label	Dimension of Column in mm
C1, C3, C31, C32	C1	300 x 450
C5, C6, C7, C2, C4, C10, C11, C12, C13, C15, C16, C17, C26, C27, C33, C34, C35	C2	300 x 500
C8, C9, C14, C18, C19, C20, C21, C22, C23, C24	C3	350 x 550
C20, C25, C21, C9, C29	C4	350 x 600

Table No 2 Beam size details of structure without TMD

Label used in software	Group label	Dimension of column in mm
B1 TO B16, B41, B46, B47, B48, B49, B50, B51, B52, B53, B54, B55	B1	300 x 400
B17 TO B40 ,B42, B43, B44, B45,B56, B58, B57	B2	300 x 500

Table No 3 Basic Building characteristics to find optimum TMD parameters

System	Fundamental Frequency (Cyc / sec)	Modal mass (kg)
RECTANGULAR BUILDING	1.422	4212532.328

By using formule mentioned in paper by Fahim Sadek et. Al the optimum parameters of TMD are calculated

Table No 4 Optimum parameters of TMD

Mass Ratio	Mass of TMD (Kg)	Natural frequency of TMD for mode 1 (Cyc / sec)
3	123777.7	1.229
3.5	142534.62	1.149
4	168106.64	1.248
4.5	177063.48	1.167
5	189003.38	1.214

Table No 5 Details of TMD

Mass Ratio	Column Size (mm)	Beam Size (mm)	Slab Thickness (mm)	Height Of Top Storey (m)
3	150 x 250	150 x 250	75	4
3.5	150 x 300	150 x 300	85	4.5
4	200 x 300	200 x 300	95	5
4.5	200 x 350	200 x 350	95	5.2
5	200 x 350	200 x 350	105	5.5

Free Vibration Analysis:

After arriving at TMD, its free vibration analysis is carried out. Natural frequency of TMD is extracted from analysis.

Table No 6. Free vibration characteristics of TMD are analyzed and tabulated

Mode	Frequency for various mass ratio cyc/sec				
	Mass Ratio 3	Mass Ratio 3.5	Mass Ratio 4	Mass Ratio 4.5	Mass Ratio 5
1	1.229	1.149	1.248	1.167	1.214
2	1.548	1.548	1.516	1.512	1.525
3	1.631	1.622	1.656	1.636	1.654
4	1.723	1.751	1.657	1.689	1.707

5	1.943	2.014	1.935	1.946	2.033

The highest frequency is obtained for mass ratio 3 and lowest frequency is observed for mass ratio 5. As mass ratio increases frequency decreases.

III. RESULT AND DISCUSSION

1. Variation in Displacement in X direction for structure with TMD & without TMD

The variation for displacement along X direction structure with TMD and without TMD G+ 6 8 structures is presented in Figure 2.

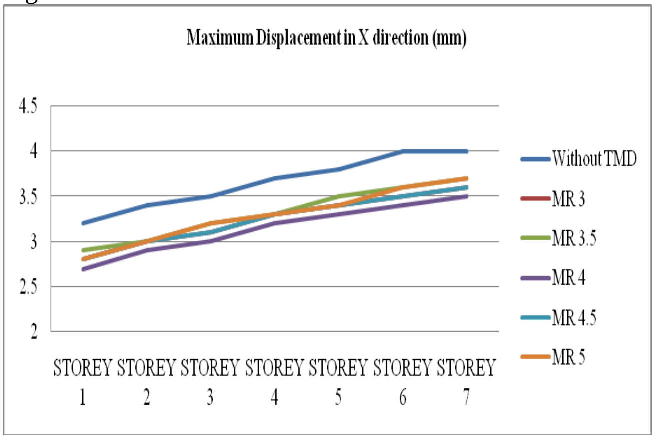

Figure No 2 Maximum Displacements in Y for G + 6 structures

The top displacement in X direction is reducing as mass ratio increases. The lowest displacement in X direction (storey wise) is observed for mass ratio 4 as shown in figure 2. The reduction in displacement is 14.28%.

2. Variation in Displacement in Y direction for structure with TMD & without TMD

The variation for displacement along X direction structure with TMD and without TMD G+ 6 structures is presented in Figure 3.

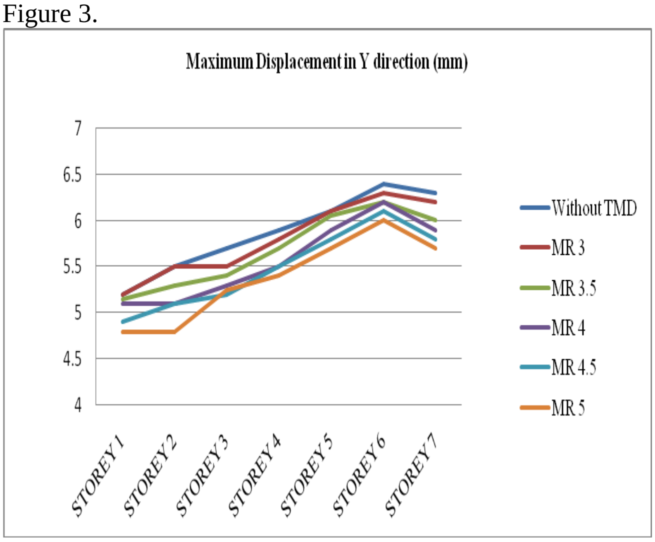

Fig 3 Maximum Displacements in Y for G + 6 structures

The top displacement in Y direction is reducing as mass ratio increases. The lowest displacement in Y direction (storey wise) is observed for mass ratio 4 as shown in graph no 3. The reduction in displacement is 10.52%.

3. Variation in Column Bending Moment for structures with TMD & without TMD

The figure below shows the variation in column bending moment for G+6 structures of each model with varying mass ratios

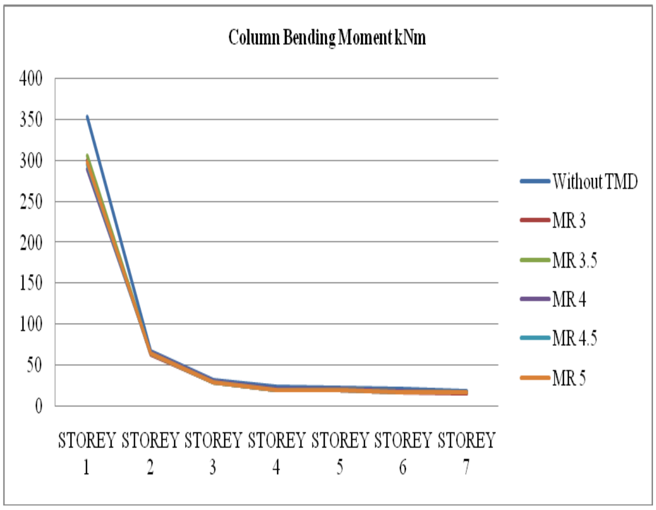

Figure No 4 Maximum Column Bending Moment for G + 6 structures

Column Bending Moment is reduced by the introduction of TMD. Lowest column bending moment is observed for Mass ratio 5. The highest reduction in column bending moment due to introduction of TMD is 19.82% i.e. at storey 1. However marginal reduction in bending moment is observed for storey 2, 3, 4, 5 for the same model.

4. Variation in Column Shear Force for structures with TMD & without TMD

The variation in Column Shear Force for structures with TMD & without TMD is presented in figure 5. It is observed that column shear forces at Ist storey is maximum.

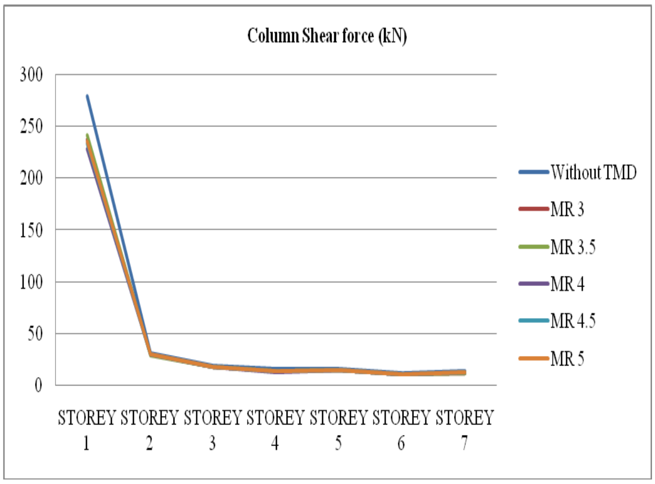

Fig 5 Maximum Column Shear force for G + 6 structures

As mass ratio is increasing reduction in column shear force is gradual. The minimum shear force is observed for mass ratio 4 at storey 1for mass ratio 4. The reduction in column shear force after introduction of TMD is 21.10% at storey 1. However marginal reduction in shear force is observed for storey 2, 3, 4, 5 for the same model.

5. Variation in Storey Shear for structures with TMD & without TMD

The variation in Storey Shear Force for structures with TMD & without TMD is presented in figure 6

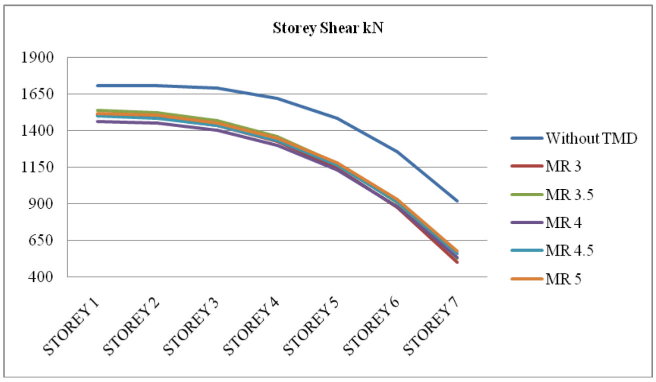

Figure 6 Maximum Storey Shear for G + 6 structures

Storey Shear is reduced with introduction of TMD. Minimum shear is observed for mass ratio 4. The reduction in storey shear is about 12.583% as compared to without TMD.

IV. CONCLUSION

The structures with TMD of mass ratio 5 are giving better seismic performance. The implemented analysis shows that the performance of structure with TMD is better than that of structure without TMD. Introduction of TMD in structure marginally reduces the frequency which in turn increases time period of structure. The increase in time period results in reduction in storey shear. As mass ratio is increased the frequency of structure is reduced.

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