

BEHAVIOUR OF TUNED MASS DAMPERS ON DYNAMIC RESPONSE OF STRUCTURE UNDER SEISMIC EXCITATION

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Abstract – To diminish the structural response due to lateral excitations, number of methods have been developed recently. Passive-damping device consist of a heavy-mass connected to structure by dashpot as well as spring-system, for example tuned mass damper (TMD). To diminish dynamic behavior, these devices are extensively used for shaking control systems. To reduce dynamic responses of tall structure TMD concept has been adopted in civil engineering constructions. Secondary mass system is predicted as of it should have a basic-frequency, which depends on its stiffness and mass which in turn is modified to that of prime construction. Building is induced with basic-frequency it tends T.M.D to vibrate away from the plane with building movement and leads to decrease in response of the building. Mass of secondary system ranges from 0.2% to 2% of construction weight. In case of multi-storey frames and towers, Multiple T.M.D s are installed to regulate seismic excited movement because, recent earthquakes are reported that they contain large number of frequency content. Hence, more than one TMDs are used and they are tuned to various structural frequency.

Key Words: damping ratio, mass distribution, mass ratio, Multiple Tuned mass Dampers (MTMD), number of dampers, Tuned Mass Dampers (TMD), structural frequency, Vibration control device.

1.INTRODUCTION

The mechanical oscillation about an equilibrium point is known as vibration. They are periodic-oscillation also non-periodic oscillation. Vibration control is an important aspect in case of space craft, plane, ship and machineries. Vibration reducing methods improved with modernization of engineering to civil and infrastructure fields.

Civil engineering constructions like multi-storey frames, Ranforced concrete-towers and road-bridges are vulnerable to external excitation because they are designed for an additional flexibility. Therefore, these flexible structures are vulnerable when they are subjected to extreme oscillations under the activities of airstream or shaking of earth.

Forceful trembling of earth crest is known as Earthquake. Due to tectonic actions sudden movement of earth crust causes the vibration of earth surface. Meanwhile these loads are arbitrary and cannot be predicted easily, to assess the physical behavior of structure subjected to earth quake forces are to be carefully modelled. Reinforced Concrete buildings are brittle in nature when they subjected to

earthquake forces of greater magnitude leads to catastrophic failure. But structures already designed are susceptible to future earthquakes. Risk is linked with seismic hazard and susceptibility of building. This can be avoided by increasing flexibility of civil engineering structures, which affects the comfort of user. So, it is essential to reduce the dynamic forces like EQ and high airstreams and is a chief topic in civil-engineering.

Buildings will dissipate energy which is forced on structure by wind and earthquake by some means. Processes like over-stressing, friction and inelastic deformations are the reason for dissipation of energy from the structure. Usually for modern massive buildings the over-all damping is nearly five percent of the severe damping. Vibration control through energy dissipation is done in structures which are equipped with artificial damping devices. They are

1. Active-control method,
2. Passive-control method,
3. Semi-active control method and
4. Hybrid-control method.

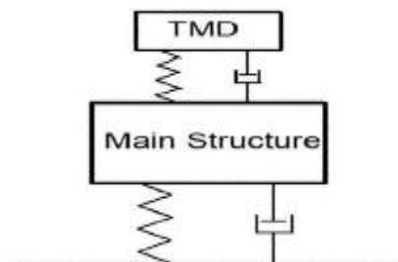


Fig.1 Schematic representation of TMD

2. METHODOLOGY

A. Scope of study

This Analogy consists of 20-storey symmetric multi-storey Reinforced Concrete building which drives to study the outcome of Single and Multiple T.M.D. in high rise building. Using linear analysis considering special Moment Resisting Space frame designed for seismic and gravity forces. The structure is designed considering IS Code 1893, under Zone five. Analogy will be carried out using SAP 2000 20 software

B. Methodology

A 20-storey symmetrical building is considered and modelled using SAP 2000 software.

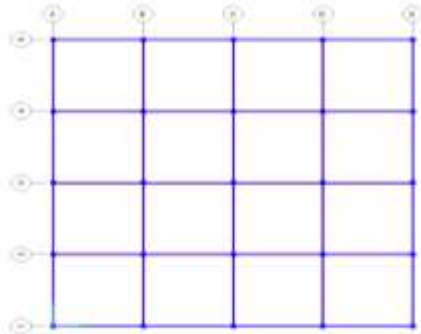


Fig.2 Plan of the Model 4 Bay 20 Storey Symmetrical Building

For the study purpose an architectural plan has been taken with a uniform storey height of 3m symmetrical multi-storey building.

Geometrical Parameters,

- | | |
|------------------------------------|----------------------------|
| 1. Building Type structure (SMRF). | - Special moment resisting |
| 2. Number of Floors | - 20 Storeys. |
| 3. Floor height | - 3 m. |
| 4. Base support | - Fixed. |
| 5. Structural type | - RCC framed. |
| 6. Concrete Grade | - M30. |
| 7. Steel Grade | - Fe500 |
| 8. Column sizes | - 250X600,600X900. |
| 9. Beams sizes | - 250x450,250x600. |
| 10. Depth of the Slab | - 150mm |
| 11. Live load | - 3KN/m ² |
| 12. Floor load | - 1KN/m ² |
| 13. Seismic zone | - Zone V |
| 14. Importance facto | - 1.5 |
| 15. Reduction factor | - 5 |
| 16. Soil type | - 1 (Rock/Hard soil) |

A TMD includes a heavyweight located at the frame's topmost, which have tendency to continue immobile. Although the frame does not remain still below floors. In which the inertial force is transmitted to the frame thereby reducing the frame vibration. Dr. B.S.Taranath defined mass of TMD as in his book "Reinforced-Concrete Design of Tall-Buildings" as "Weight of the Tuned-damper is considered about 0.25 % to 0.70 % of total-mass of the frame which is equal to 1 % to 2 % of basic modal weight." So, in this work the weight of the damper is varied from 0.2% to 2% of the building total weight.

The frame is modelled using SAP 2000 Software.

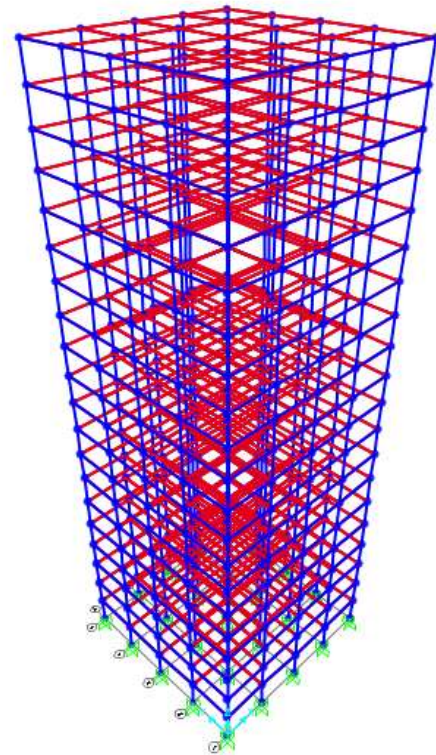


Fig. 3 20-Storey Space-Frame (Reinforced Concrete structure) Without-TMD

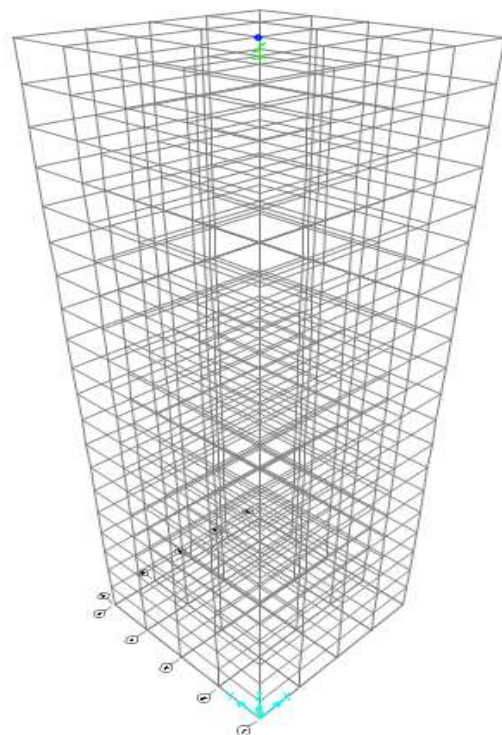


Fig. 4 20-Storey Space-Frame (Reinforced Concrete structure) With- 0.2% TMD

To define the structural performance of the object in the model, properties are assigned to each and every object. Materials and Section properties are named such as M30, HYSD500 before assigning the specified properties. To define frames section property, go to "Define" option click "Section property" and go for "Frame sections" and add new property. Give section name and define dimensions in it. Set up the material as M30 and concrete reinforcement design type as "Beam." Go to "Define" option click "Section property" and go for "Frame sections" and add new property. Give section name and define dimensions in it. Set up the material as M30 and concrete reinforcement design type as "column." To define the slab section, go to define option select section property and go for "Area Sections." Select section type to add as "Shell."

well as auto lateral load pattern. To define seismic load patterns, select define command define EQ load as per codal provision (IS 1893:2002).

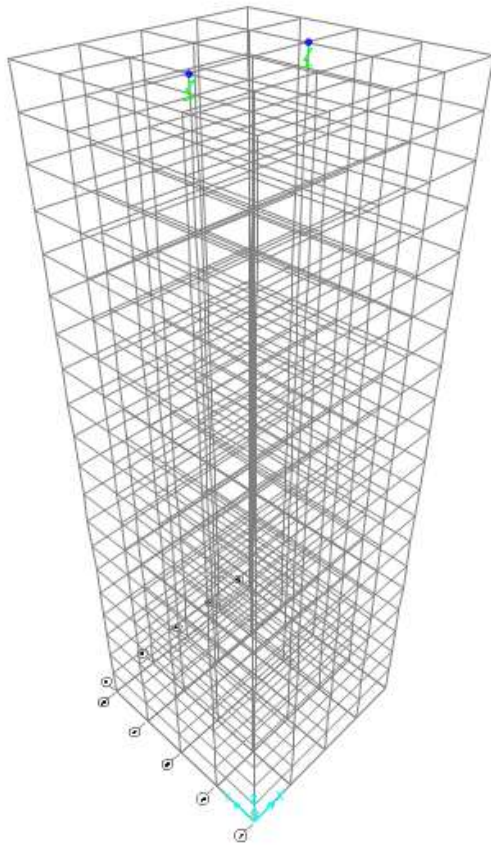


Fig. 5 20-Storey Space-Frame (Reinforced Concrete structure) with- 2 TMD 2%

Define the load case name, and assign precise load values to the parameters as part of load case or define predefined lateral load in case of seismic or wind. Values which we assign indicates type of load, its magnitude and its direction of action.

To define Earthquake parameters, go for "load pattern" and name the load pattern and assign self-weight multiplier as

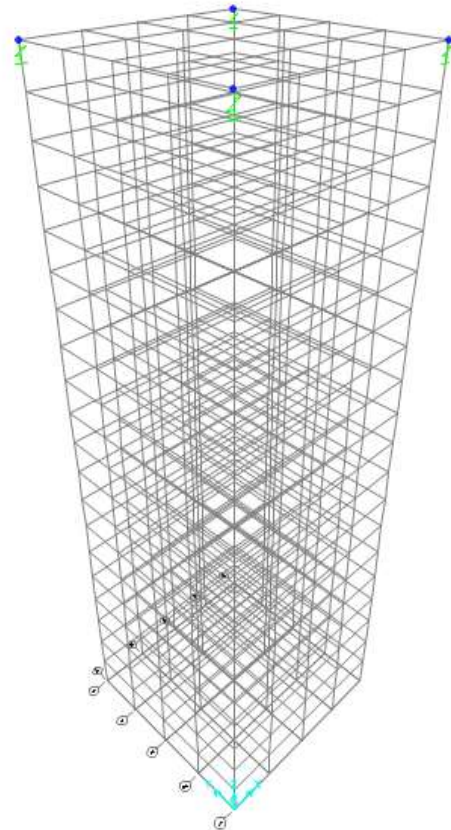


Fig. 6 20-Storey Space-Frame (Reinforced Concrete structure) With- 4 TMD 2%

To define Time History (TH) function, go to "functions" select Time History. Choose function type to add as from file, the Time History data i.e. acceleration defined by Bhuj earthquake data. Browse it and upload to time history definition. Add header line to skip, prefix character per linear.

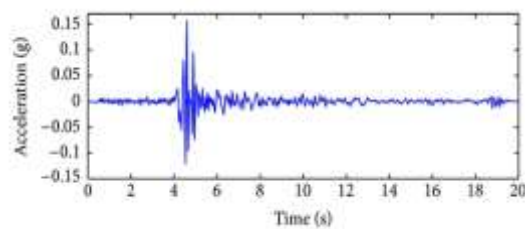


Fig. 7 Time History graph of Bhuj earthquake

3. RESULTS AND DISCUSSION

Table -1: Geometrical parameters of Single Tuned mass dampers with different mass ratios

W (kN)	94636.3
ω (rad/sec)	3.4099
	3.4099
	3.8808

W(kN)	94636.28						
μ	0.20%	0.40%	0.60%	0.80%	1%	1.50%	2%
md (kN)	189.273	378.545	567.818	757.09	946.363	1419.54	1892.73
md (kg)	19300.1	38600.3	57900.4	77200.5	96500.6	144751	1930001
fr	0.998	0.996	0.994	0.99206	0.9901	0.98522	0.98039
ξ	0.02736	0.03865	0.04729	0.05455	0.06093	0.07444	0.08575

Damper frequency, ωd(rad/sec) = fr *ω							
μ	0.20%	0.40%	0.60%	0.80%	1%	1.50%	2%
M 1	3.5243	3.5173	3.5103	3.50341	3.49647	3.47924	3.46219
M 2	3.5243	3.5173	3.5103	3.50341	3.49647	3.47924	3.46219
M 3	3.9748	3.9669	3.959	3.95117	3.94334	3.92392	3.90468
Stiffness, k (kN/m) = ωd 2* md							
M 1	2351.01	4683.3	6997.05	9292.41	11569.6	17183.8	22687.6
M 2	2351.01	4683.3	6997.05	9292.41	11569.6	17183.8	22687.6
M 3	2990.36	5956.92	8899.89	11819.5	14715.9	21856.9	28857.5
Effective damping, c(kN-m/sec) = 2*ζ*md*ωd							
M 1	36.5004	102.93	188.532	289.4	403.248	735.347	1123.83
M 2	36.5004	102.93	188.532	289.4	403.248	735.347	1123.83
M 3	41.1654	116.086	212.627	326.387	454.78	829.329	1267.46

Similarly, the Geometrical parameter of Multiple Tuned mass damper with 2% mass ratio 20-storey RC building can be calculated using above table.

A comparative study of effect of Tuned Mass Damper and Bare frame of 20-storey RC building for a Time History data of Bhuj earthquake has been done for various percentages of mass ratio at optimum damping. For each and every mode, ratio of damping is considered as 5%, which is tuned to basic frequency of frame

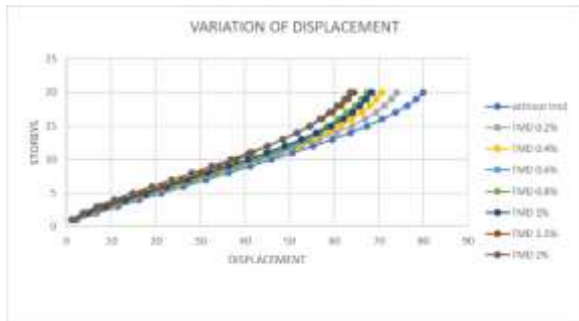


Fig.8 (a) Comparing of Displacement without and with TMD along EQX &EQY for various mass ratios

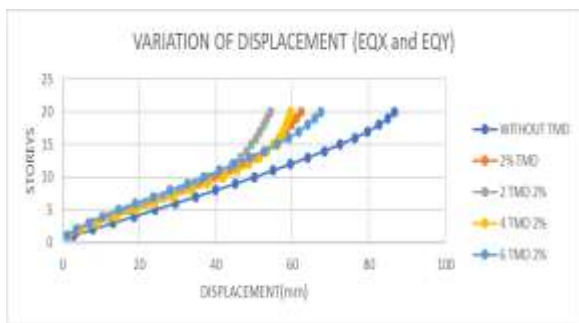


Fig.8 (b) Comparing Displacements with Single and Multiple TMD of mass ratio 2% along EQX &EQY

From the above graphs, it has been found that by using 2 % of mass ratio the displacement reduction is found to be maximum of about 20.40%. So, 2% TMD is considered as optimum Tuned Mass Damper. As 2% mass ratio is considered as optimum, displacement is checked for number of tuned mass damper and it has been found that reduction in displacement is maximum for 2 TMD and it is about 36.92% along EQX and EQY directions in contrast of without-TMD.

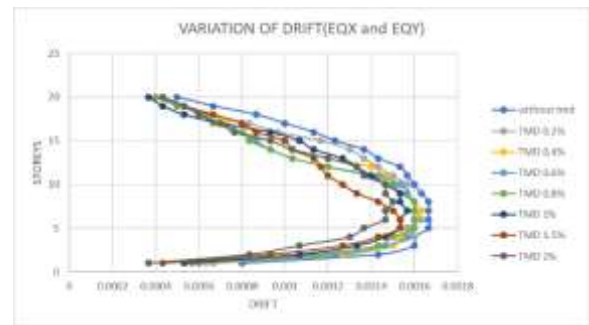


Fig. 9 (a) Comparing Drifts without and with TMD along EQX &EQY for various mass ratios.



Fig. 9 (b) Comparing Drifts with Single and Multiple TMD of mass ratio 2% along EQX &EQY

As per IS code 1893: 2002 clauss 7.11, Inter-storey drift with LF equal to one with respect to lateral loads, storey-drift less than or equal to $0.004 \cdot \text{floor height}$. From the above graphs, we conclude that Drifts observed are within the range that is for 2% TMD it is 0.00150 and for 2 TMD 2% mass ratio it is 0.00140 times the storey height. From above graphs using Tuned Mass Damper with 2 %mass-ratio the Drift reduction is found to be 11.76% and for Multiple(two) TMD 2% which is reduced by 17.64 % along EQX and EQY directions.

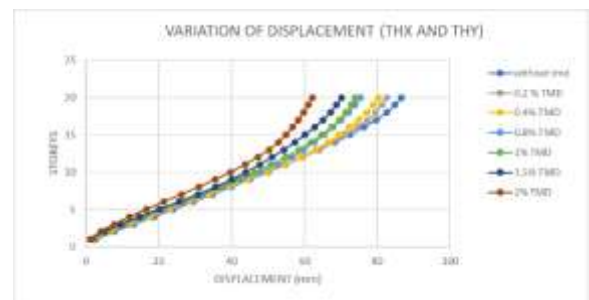


Fig. 10 (a) Variation in Displacement without and with TMD along THX & THY for various mass ratios

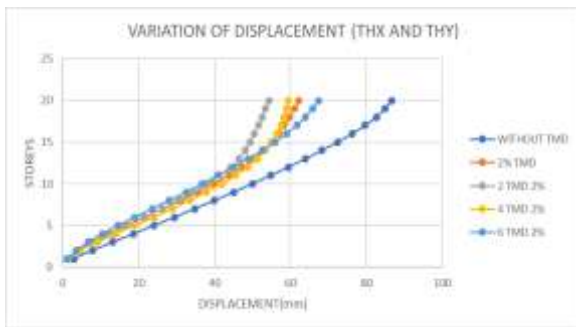


Fig. 10 (b) Variation in Storey-Displacements with Single and Multiple TMD of mass ratio 2% for THX & THY load case

From the above graphs, it has been found that by using 2 % of mass ratio the displacement reduction is found to be maximum of about 28.22%. So, 2% TMD is considered as optimum Tuned Mass Damper. As 2% mass ratio is considered as optimum, displacement is checked for number of tuned mass damper and it has been found that reduction in displacement is maximum for 2 TMD is about 39.51% along THX and THY direction in comparison to without TMD

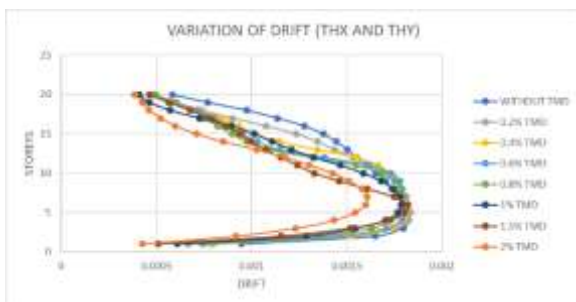


Fig. 11 (a) Comparing Inter-storey Drifts without and with TMD along THX & THY for various mass ratios.

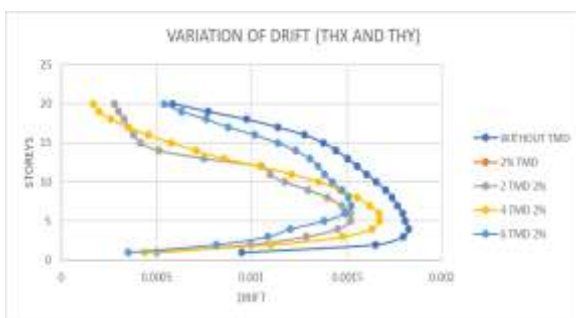


Fig. 11 (b) Comparison of Inter-storey Drift with Single and Multiple TMD of mass ratio 2% along THX & THY

As per IS code 1893: 2002 claus 7.11, Inter-storey drift with load factor equal to one with respect to lateral loads, storey-drift less than or equal to $0.004 \times$ floor height. From the above graphs, we conclude that Drifts observed are within the range that is for 2% TMD it is 0.00161 and for 2 TMD 2% mass ratio it is 0.00152 times the storey height. From above

graphs using Tuned-Mass-Dampers of 2 % of mass-ratio the Drift reduction is found to be 11.11% and for Multiple(two) TMD 2% it is reduced by 16.67% along THX and THY directions.

Table 1 Variation of Base shear

% OF TMD	BASE SHEAR(KN)
0	4268.605
0.2	4947.169
0.4	5222.865
0.6	5474.813
0.8	5710.175
1	5796.809
1.5	6786.095
2	6343.731
2 TMD 2%	14157.212
4 TMD 2%	6391.072
6 TMD 2%	8349.806

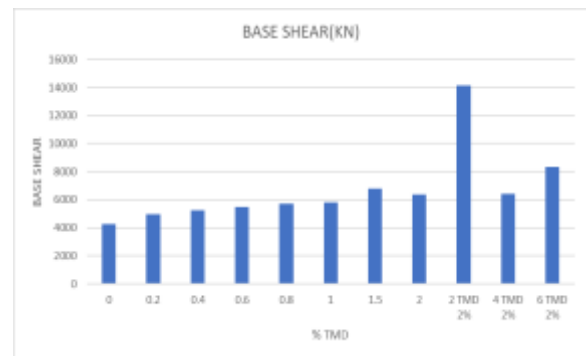


Fig. 12 Variation of Base Shear (KN)

From the above graph it has been found that Base Shear increased by 1.4861 times as of Single-TMD of 2% mass ratio compared to bare frame and in case of multiple TMDs (2 TMD 2% mass ratio) it has been increased by 3.31 times. Since, base shear is abruptly increased in case of 2 TMD with 2% mass ratio, 4 number of TMD with 2% mass ratio is optimum that is 1.49 times compared to bare frame

Time-Period variations for various% of TMD

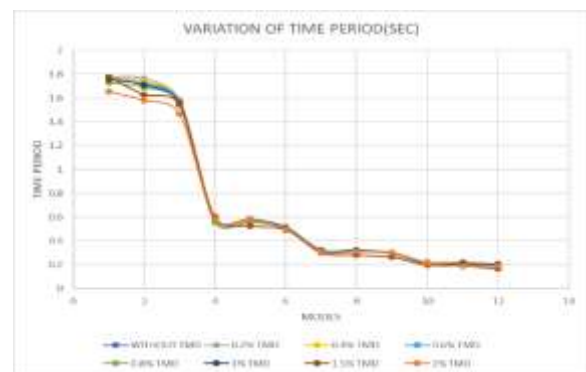


Fig. 12 (a) Variation of Time Period for different modes (without, with TMD of various mass ratios).

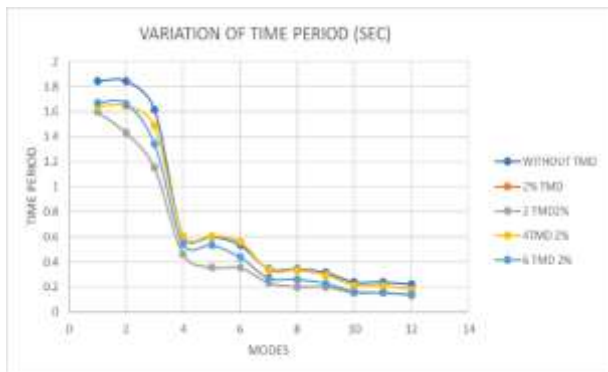


Fig.12 (b) Time-Period variation.

From the above graphs Time period has been decreased in the different modes with Single and Multiple Tuned Mass Dampers in comparison to frame without TMD.

4. CONCLUSIONS

This effort is attentive on capability of Tuned Mass Damper to diminish the seismic made frame oscillation. The models are created by SAP2000 software and Time-History study is done by Bhuj earthquake data. This analysis shows comparison between Bare frame, single and multi-tuned mass dampers of various mass ratios.

The percentage variation in response of RC building for various cases are as follows:

It has been found that by using 2 % of mass ratio the displacement reduction is found to be 20.40% and for Multiple(two) TMD 2% it is reduced by 36.92% along EQX and EQY directions.

It has been found that by using 2 % of mass ratio the displacement reduction is found to be 28.22% and for Multiple(two) TMD 2% which is reduced by 39.51% along THX and THY directions.

Drifts values in case of Equivalent Static analysis are within the specified range It has been found that by using 2 % of mass ratio the Drift reduction is found out to be 11.76% and for Multiple(two) TMD 2% which is reduced by 17.64 % along EQX and EQY directions.

Drifts values in case of Time History analysis are within the specified range. It has been found that by using just 2 % of mass ratio the Drift reduction is found out to be 11.11% and for Multiple(two) TMD 2% it is reduced by 16.67% along THX and THY directions.

Base shear has been increased by 1.4861 times in case of Single Tuned Mass Damper and 3.31 times in case of 2 TMD with mass ratio 2% as compared to Bare Frame. 4 number of TMD with 2% mass ratio is optimum that is 1.49 times compared to bare frame.

Time period has been decreased in the structure with Single and Multiple Tuned Mass Dampers compared to Bare Frame.

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BIOGRAPHIES



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