Analysis of High Rise Structure using Tune Mass Damper

Khemraj S. Deore[1] Prof. Dr. Rajashekhar S. Talikoti[2] Prof. Kanhaiya K. Tolani[3]
[1]ME Student [2]Head of Dept. [3]Associate Professor
[1,3]Late G. N. Sapkal College of Engineering, Nashik, Maharashtra India [2]Sandip Foundation's Sandip Institute of Technology and Research Centre, Nashik, Maharshtra

Abstract— Tall Buildings are increasing day by day built all over. As safety of users is the importance prime factor, so the structural stability is the main concern of Structural Engineering. Most of the structures are found to have very low natural damping. In order to increase the damping capacity of a structure various mechanical means to increase damping are being considered now days in high rise buildings. A Tuned mass damper (TMD) is a device consisting of a mass, and spring that is attached to a structure in order to reduce the dynamic response of the structure. For Analysis purpose symmetrical moment resistance frame (MRF) of 10th, 15th, 20th, 25th and 30th storey are modeled with and without tuned mass damper by using software ETABS. A tuned mass damper (TMD) is placed on top floor of building and Linear static analysis is perform. The result obtained from software analysis of 10th, 15th, 20th, 25th and 30th storey building with and without tuned mass damper are compare with each other.

Key words: TMD, Linear Static Analysis, Story Displacement, Story Drift, Base Shear, ETABS

I. INTRODUCTION

An earthquake is a natural phenomenon associated with violent shaking of the ground. They are vibrations of the earth's surface caused by sudden movements of earth crust mostly due to tectonic movements.Since earthquake forces area unit random in nature and unpredictable, the engineering tools must be sharpened for analyzing structures below the action of those forces. Time History Analysis and Equivalent Static analysis is a vital technique for structural seismic analysis particularly once the structural is high rise.

This thesis study of the damper effect in the frame (MRF) is an important factor for the analysis. For Analysis purpose symmetrical moment resistance frame (MRF) of 10th, 15th, 20^{th}, 25^{th} and 30th storey are modeled with and without tuned mass damper by using software ETABS. Constant loading parameters are used for both cases, also same plan is used for various models of analysis. Load combinations are taken from IS code 875 Part 5.

A tuned mass damper (TMD) is placed on top floor of building and Linear static analysis is perform. The result obtained from software analysis of 10th, 15th, 20^{th}, 25^{th} and 30th storey building with and without tuned mass damper are compare with each other.

A. Tuned Mass Damper

A tuned mass damper (TMD) may be a device consisting of a mass, a spring, and a damper that's hooked up to a structure so as to scale back the dynamic response of the structure. The frequency of the damper is tuned to a selected structural frequency thus as that frequency is happy, the damper can resonate out of spare the structural motion. Energy is dissipated through the damper inertia pressure engaged at the form. The Tuned Mass Damper (TMD) construct was first applied by Frahm in 1909 (Frahm, 1909) to cut back the rolling motion of ships furthermore as ship hull vibrations. The natural frequency of the TMD is tuned in resonance with the fundamental mode of the primary structure, so as that associate degree oversize amount of the structural moving energy is transferred to the TMD and so dissipated by the damping because the primary structure is subjected to external disturbances. It's been evidenced that a TMD is an efficient and possible system to use in structural vibration management against high earthquake masses.

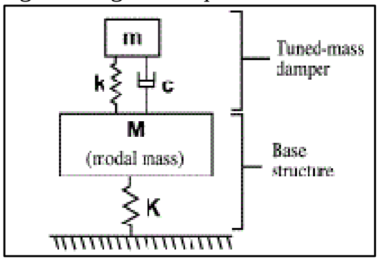

Fig. 1: A schematic representation Tuned Mass Damper (TMD)

B. Objectives

1) Analysis of symmetrical moment resistance frame (MRF) 10^{th}, 15^{th}, 20^{th}, 25^{th} and 30^{th} storey three - dimensional model by using software ETABS.
2) To search out the unstable response (storey drift, structure displacement and base shear) of a symmetrical MRF building with and with none damping device victimization ETABS.
3) A tuned mass damper (TMD) is placed on its top and through it to study its effects on Storey drift, storey displacement and base shear and analysis with and without the tuned mass damper (TMD) in ETAB.
4) The result obtained from software analysis of 10th10th, 15th, 20^{th}, 25^{th} and 30th storey building with and without tuned mass damper and compare result with each other.

C. Scope of the Study

1) The aim of the present work is to study the effect of TMD on the response of multi-storey frame structures under earthquake excitations.
2) The scope of the work includes the modelling of moment resistance frame (MRF) 10^{th}, 15^{th}, 20^{th}, 25^{th} and 30th storey three - dimensional model by using software ETABS.
3) A tuned mass damper (TMD) is placed on its top and through it to study its effects on Storey drift, storey displacement and base shear and analysis with and without the tuned mass damper (TMD) in ETAB.

II. LITERATURES

In this section, we summarize the investigations of various authors working in the field of Structural control as part of the literature survey.

Webster, Vaicaitis (2003)[1] In this paper author describe the successful implementation of a tuned-mass damping system to reduce the steady-state vibrations of the long span, cantilevered, composite floor system at the Terrace on the Park Building in New York City. And concluded used of TMD substantially reducing the vibrations of an existing composite floor system. The critical reasons for the success of the system are: its tunability, which helped ensure that the theoretically predicted performance could be approximated by the actual as-built system; and the cost of the system, which was about an order of magnitude less than the cost of recommended structural corrective measures.

DongXu (2009) [2] visco-elastic (VE) dampers are one of the most common earthquake mitigation devices. This paper addresses the mathematical modelling of VE dampers and the dynamic analysis of structures with VE dampers. In this paper, the equivalent standard solid model, a new mathematical model of VE dampers, is used to describe the influence of temperature on the energy absorption features of VE dampers. Elastoplastic time field analysis, frequency field analysis and shaking table tests are used to analyze responses of a 1/5-scale three-story reinforced concrete frame structure with and without VE dampers. Comparisons between the numerical and experimental results show that the VE dampers can be modeled by the equivalent standard solid model and that the VE dampers are effective in reducing the seismic responses of structures.

Shetty et all (2012)[3] In this study Dynamic response of a base isolated multi-storey plane frame structure with Multiple Tuned Mass Dampers (MTMD) subjected to harmonic ground excitation and Mexico earthquake excitations. And concluded that the effectiveness of MTMD in suppressing the dynamic response of base isolated structure is determined by comparing the response of corresponding structure without MTMD. The reaction of base isolated shape with MTMD is found to be much less as compared to the corresponding reaction whereas now not MTMD, implying that the MTMD is powerful in lowering forces and displacement of a base isolated shape.

Jester (2012)[4] They stated that there are two types of visco-elastic (VE) seismic dampers for building structures, the VE diagonal damper and the VE passive mass damper which are studied in this thesis. The thesis reviews the relevant theoretical considerations in earthquake engineering and discusses the properties of VE materials important in damper design. It presents analytical equations for decisive the damping additional for every system. It is complete that each VE diagonal dampers and VE passive mass dampers were effective at reducing the seismal response of the example.

It is all over that each VE diagonal dampers and VE passive mass dampers were effective at reducing the seismal response of the image. The mass dampers were somewhat higher at reducing the bottom shear and moment response. Mass dampers conjointly gave the impression to have some benefits in style, as well as larger skillfulness, and higher economy with in the use of VE material

Suryawanshi et al (2012) [5] during this study of investigate tuned mass damper systems as vibration controller in multi-storeyed building, and study regarding its analyze the effectiveness of their use in giant structures, so as to preserve structural integrity. The idea in the back of a tuned mass damper is that if a more than one-diploma-of-freedom machine carries a smaller mass set up thereto, and therefore the parameters of the smaller mass place unit tuned precisely, then the oscillation of the machine are frequently decreased by using the smaller mass. The thesis report describes the history and inner-workings of tuned mass dampers, and investigates the technology of tuned mass dampers in the Taipei Tower in Taiwan, the tallest building in the world. It requires a mass damper tuned to the fundamental mode of the structure, consisting of a massive steel sphere, in order to counteract the building's oscillations and concluded tuned mass damper technology is an essential part of maintaining the structural integrity of structures.

Umachagi et all (2013)[6] Presents an outline of literature associated with the behavior of dampers on seismically affected structures. The review includes differing types of dampers like aluminiferous dampers, elastic dampers, and resistance dampers. They try to supply an outline of various styles of seismal response management devices, and highlight a number of the recent developments. The experimental and analytical investigations carried out by various researchers clearly demonstrate that the seismic control method has the potential for improving the seismic performance of structures And concluded that controlling devices reduce damage significantly by increasing the structural safety, serviceability and prevent the building from collapse during the earthquake.

Khan(2014)[7] In this paper author has describes the results of an extensive study on the seismic behavior of a structure with damper and without damper under different earthquake acceleration frequency like EQ Altadena, EQ Lucerne, EQ Pomona, EQ Smonica and EQ Yarmouth Proposed system is placed the dampers on the floors of the ninth-floor and 5-floor of a ninth story constructing frame then examine the distinctive overall performance of shape with damper as much as ninth-flooring, damper up to fifth-floors and without damper of 9th-tale constructing frame the use of SAP2000 V15. As per IS-1893 2002 non-linear time-history analyses of body shape imply that maximum displacement, most base shear and maximum acceleration successfully lessen with the aid of providing the damper in building body from base assist to fifth- ground and base guide to ninth-floor contrast to as traditional frame.

Kim, Lee (2014)[8] In this work analysis of a structure installed with visco-elastic dampers the modal strain energy method has been generally applied to predict the equivalent damping ratios of the system. The method derives the equivalent damping ratios supported the belief that the damping is proportional to mass and/or stiffness of the structure system. In this study some of efficient analytical procedures are applied to obtain the seismic response of a non-proportionally damped building structure with added visco-elastic dampers; the complex mode superposition method, direct integration method combined with matrix condensation, modal strain electricity method, and the method disregarding the off-diagonal terms of a converted damping matrix. unique attention has been paid for the derivation of the complicated modal superposition procedure, and the reliability of the approximate strategies is checked by way of comparing the approximate answers with those received from the complex mode superposition.

Murad, Lavanyag (2016)[10] This paper is to study the comparison of shear wall and TMD for reducing vibration of all buildings due to wind earthquake loading by using SAP2000 software. Shear walls and Tuned Mass Dampers square measure appointed within the structure as an alternative. numerous arrangements of Tuned Mass Dampers during this thirty level building square measure studied, complete the value of TMDs is sort of like that of shear enclose thirty storey's structure. But less base shear, storey displacement, joint acceleration, and frequency makes TMDs more applicable than shear wall.

III. Methodology

Tuned mass damper made with welded steel work is attached on the top of the structure consists of a mass (m2), spring and a damper, which is attached to one side of the building to control the responses in two directions. Steel is used because it's more prone to vibration and high damping capacity. Furthermore, by placing the TMD centrically, the torsional response of the building may also be controlled.

1) Intensive literature survey by referring books, technical papers distributed to know basic construct of topic.
2) Choice of form of structures.
3) Modeling of the chosen structures.
4) Analytical work is to be distributed.
5) Interpretation of result and conclusion

In the present work Tuned mass damper (TMD) is placed on its top and through it to study its effects on Storey drift, storey displacement and base shear and analysis with and without the tuned mass damper (TMD) in ETAB.

For investigation of the dynamic response of the structure with TMD, the following assumptions are adopted.

- The columns are assumed to be inextensible so that there is no axial deformation in the columns.
- The slab is assumed to be rigid and there is no bending deformation in the slab.
- The self-weight of the columns is neglected

IV. Problem Statement

A RCC rise building of 30 stories subjected to earthquake loading in Zone 3 has been considered .In this regard, ETABS software have been considered as tool to perform. Displacements, Story drift and Base Shear have been calculated for five different models. The plan of the building as shown in Figure has been considered to carry out the study. The Lateral Force at every Floor Level as per IS 1893(Part 1):2002.

A. *Plan of Model*

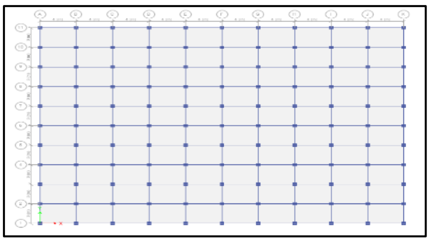

Fig. 2: Plan of Model

1) *3D view- Without Tuned Mass Damper*

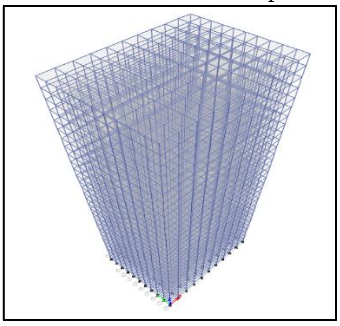

Fig. 3: 3D view Without Tuned Mass Damper

2) *3D view- With Tuned Mass Damper*

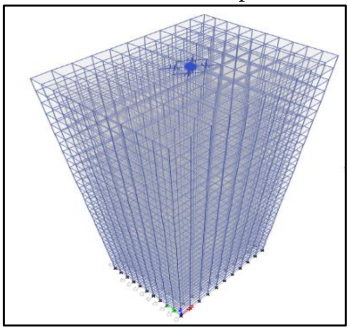

Fig. 4: 3D view- With Tuned Mass Damper

B. *Modeling and Analysis*

1) Number of Models: 5 Nos
2) Number of Floors: 10,15,20,25,30th
3) Storey height: 3m
4) Size of column: 300X750 mm
5) Size of beam Size of beam:- 230x600 mm
6) Thickness of Slab: 125 mm
7) Density of concrete: 25kn/m^3
8) Dead Load
9) External Wall Load: 11.76 kn/m
10) Internal Wall Load: 7.65 kn/m
11) Floor finish: 1.5 kn/m^2
12) Live load: 3 kn/m^2
13) Importance factor (I):-1.5
14) Soil Type: 2 (Medium)
15) Seismic zone: III
16) Zone Factor: 0.24
17) Responded reduction factor: 5

C. *Model Description*

- M1 10th floor
- M2 15th floor
- M3 20th floor
- M4 25th floor
- M5 30th floor

Parameter	Numerical value
Mass of Rigid Slab(m_1)	150×10^3(kg)
Mass of the Tuned Mass Damper(m_2)	7500(kg)
Fundamental frequency of the structure(ω_1)	36.5158(rad/sec)
Equivalent Stiffness of the column(k_1)	200×10^3(kN/m)
Stiffness of the TMD (k_2)	10×10^3 (kN/m)

Fig. 5: Model Description

V. RESULTS AND DISCUSSION

A. Storey Displacement

1) Storey Displacement X- Direction

The maximum story displacement of structures with and without TMD under earthquake. It's been shown that the maximum displacement in X-direction of the top storey without TMD is 69.1 mm and that of with TMD is 42.7 mm in an 10th storey structure, In comparison with an 10th storey structure. In a 15th storey structure, the maximum displacement of the top storey without TMD is 185.7 mm and that of with TMD is 118.1 mm. In a 20 storey structure the maximum displacement of the top storey without TMD 333.2 mm and that of with TMD is 231.67 mm. In a 25 storey structure the maximum displacement of the top storey without TMD 530.4 mm and that of with TMD is 282.7 mm. Whereas, In a 30 storey structure the maximum displacement of the top storey without TMD 530.4 mm and that of with TMD is 282.7 mm. Top storey displacement reductions were obtained after analysis.

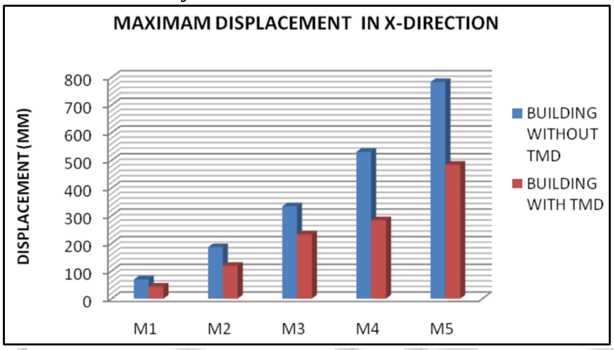

Fig. 6: Maximum displacement in X-Direction

2) Storey Displacement Y- Direction

The maximum displacement time histories of structures with and while not TMD below earthquake. It's been shown that the utmost displacement in Y-direction of the highest structure while not TMD is seventy three. 5 millimeter which of with TMD is forty five.4 millimeter in associate degree tenth structure. compared with associate degree tenth structure, in a very fifteenth structure, the utmost displacement of the highest structure while not TMD is 166 millimeter which of with TMD is one zero five.5 mm. In a 20 storey structure the maximum displacement of the top storey without TMD 302.8 mm and that of with TMD is 210.53 mm. In a 25 storey structure the maximum displacement of the top storey without TMD 491.5 mm and that of with TMD is 261.9 mm. Whereas, In a 30 storey structure the maximum displacement of the top storey without TMD 740.8 mm and that of with TMD is 457.52 mm. Top storey displacement reductions were obtained after analysis.

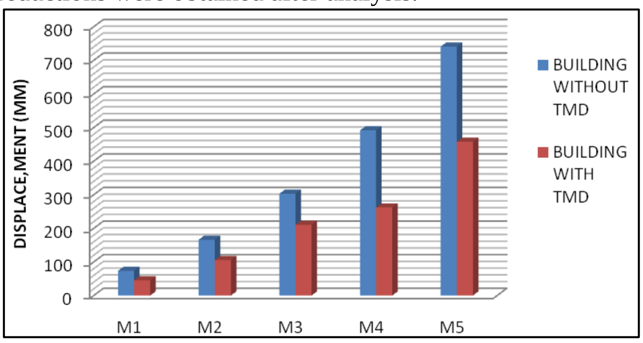

Fig. 7: Maximum displacement in Y-Direction

B. Storey Drift

It is seen that the story drift values square measure slightly high for the highest floor whereas mistreatment TMDs five-hitter for X–direction excitation and Y-direction excitation severally. Within the case of a symmetrical MRF building the story height is 3m and base story height is a pair of.5m. in step with the story drift limitation given in IS 1893.(Part I): 2002 each storey drifts must be limited to 0.004 times the storey height.

1) Storey Drift in X-Direction (M1)

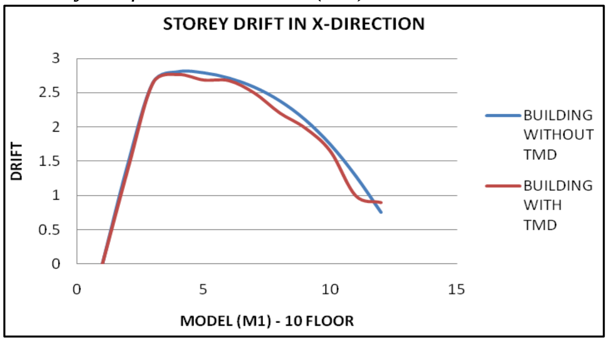

Fig. 8: Storey Drift in X-Direction (M1)

2) Storey Drift in Y-Direction (M1)

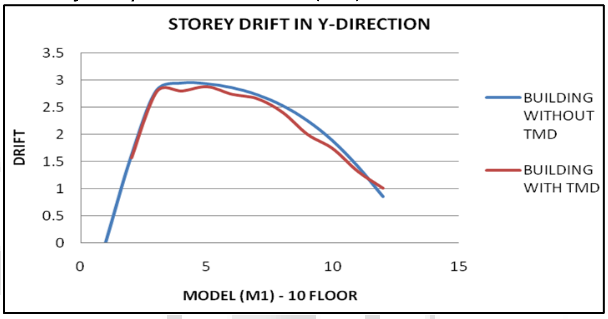

Fig. 9: Storey Drift in Y-Direction (M1)

3) Storey Drift in X-Direction (M2)

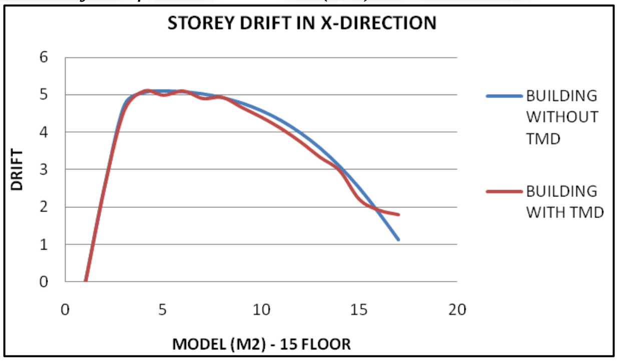

Fig. 10: Storey Drift in X-Direction (M2)

4) Storey Drift in Y-Direction (M2)

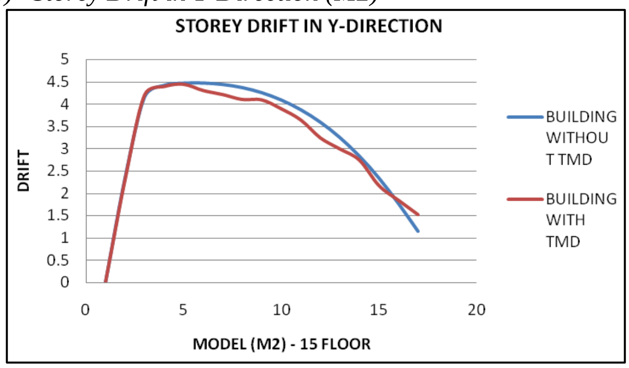

Fig. 11: Storey Drift in Y-Direction (M2)

5) *Storey Drift in X-Direction (M3)*

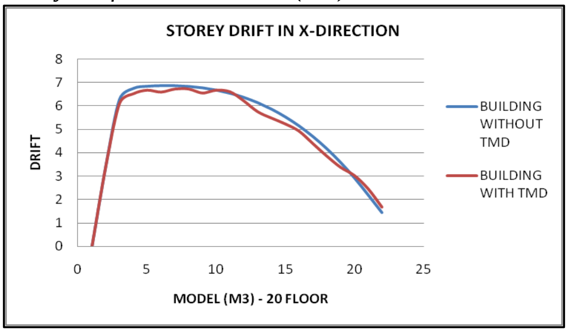

Fig. 12: Storey Drift in X-Direction (M3)

6) *Storey Drift in Y-Direction (M3)*

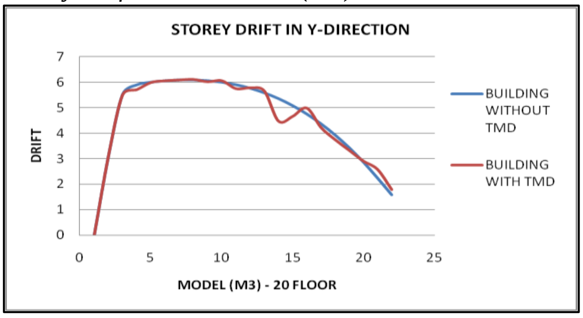

Fig. 13: Storey Drift in Y-Direction (M3)

7) *Storey Drift in X-Direction (M4)*

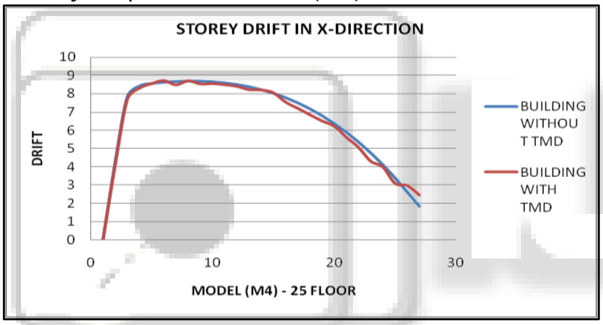

Fig. 14: Storey Drift in X-Direction (M4)

8) *Storey Drift in Y-Direction (M4)*

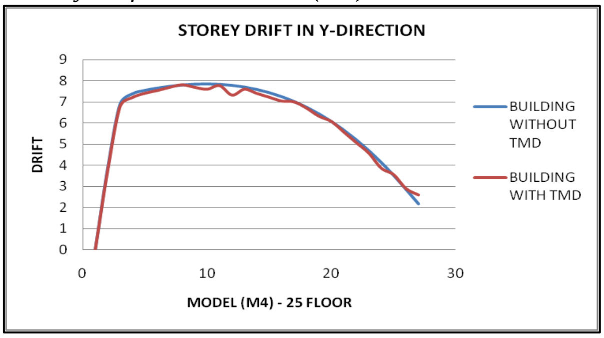

Fig. 15: Storey Drift in Y-Direction (M4)

9) *Storey Drift in X-Direction (M5)*

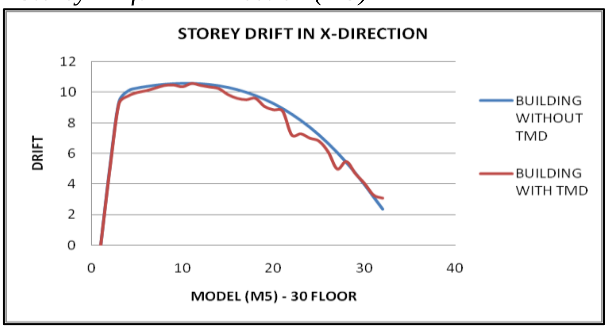

Fig. 16: Storey Drift in X-Direction (M5)

10) *Storey Drift in Y-Direction (M5)*

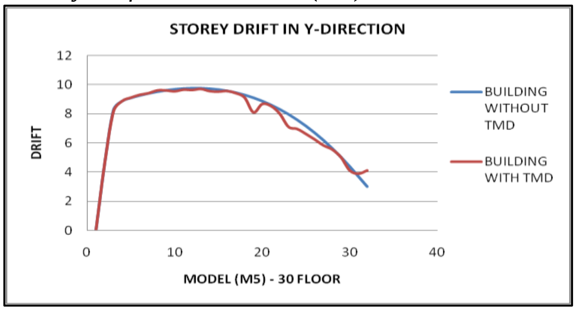

Fig. 17: Storey Drift in X-Direction (M5)

C. Base Shear

Then, Base shear were obtained once analysis for MRF symmetrical building frame, buildings while not TMD & with TMD.

TIME HISTORY	MODEL	BASE SHEAR (KN)	
		BUILDING WITHOUT TM	BUILDING WITHOUT TMD
X,Y	M1	2612.15	2670.07
X,Y	M2	2590.35	2667.38
X,Y	M3	2127.98	2179.78
X,Y	M4	2659.97	2724.71
X,Y	M5	3191.97	3269.66

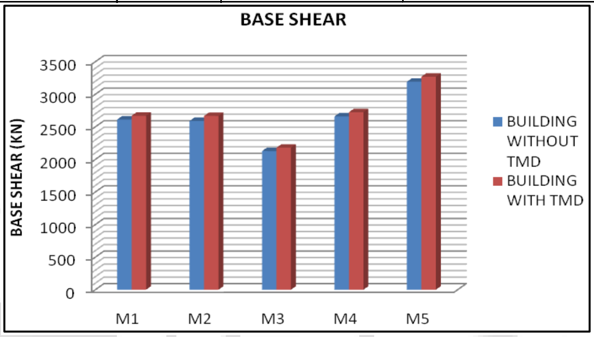

Fig. 18: Base Shear

VI. Conclusion

The seismic behavior of 10th, 15th, 20th, 25th and 30th storey building with tuned mass damper and without tuned mass damper was studied. TMD is effective in reducing displacement and story drift thereby, can be used for structures under earthquake. This study is aimed as tuned mass dampers in reducing structural (storey drift, storey displacement and base shear) of seismically excited 10th, 15th, 20th, 25th, and 30th storey building

1) It has been found that the TMDs can be successfully used to control vibration of the structure.
2) For the regular building frame, TMD is found to effectively reduce top storey displacement. The reduction of 10th storey building is 26.4 mm, reduction of 15th top storey building is 67.6, reduction of 20th top storey building is 101.53, reduction of 25th top storey building is 247.7, and reduction of 30th top storey building is 299.3mm.
3) And reduction of base shears by about 2%.
4) Therefore, the TMD should be placed at top floor for best control of deflection and base shear.

References

[1] Webster, A.C., and Vaicaitis, R. "Application of Tuned Mass Dampers To Control Vibrations of Composite Floor Systems" Engineering Journal, pp116-124, 2003

[2] Umachagi, V., and Katta, V., Reddy, G. R "Applications of Dampers For Vibration Control of Structures": IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308,. 2013
[3] Murad, M.K., and Lavanyag "Dynamic resistance of tall buildings by using tuned mass damper's" International Conference on Current Research in Engineering Science and Technology (ICCREST), 2016
[4] Shetty, K.K., Moorthy, K., Nayak, G. and Nivedita, K. R. "Dynamic Response Control of Base Isolated Plane Frame Structure Using Multiple Tuned Mass Dampers" Bonfring International Journal of Industrial Engineering and Management Science, Vol. 2, No. 4, 2012
[5] Mohite, A. A., and Patil, G.R. "Earthquake Analysis of Tall Building with Tuned Mass Damper" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320–334X PP 113-122, 2015
[6] Suryawanshi, Y. R., and Rahane, A. S. "Study of Tuned Mass Dampers System as Vibration Controller in Multistoried buildings" © 2012 IJAIR. ALL RIGHTS RESERVED ISSN: 2278-7844, 2012
[7] Khan, W., Akhtar, S., and Hussain, A. "Non-linear Time history analysis of tall structure for seismic load using damper", International Journal of Scientific and Research Publications, Volume 4, Issue 4, 2014
[8] KIM, J., And LEE, Y.C. "Dynamic Analysis of multyStroried Regular Building", IOSR Journal of Mechanical and Civil Engineering" (IOSR-JMCE), e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 1 Ver. II , PP 37-42, 2008
[9] Jester, T.P. "Earthquake Analysis of High Rise building with and without in filled Walls", International Journal of Engineering and Innovative Technology (IJEIT), Volume 2, Issue 2, 2012
[10] Xu, Z.D. "Seismic Damage and Damage-Control Design for RC Frames" J. Intell. Mater. Syst. and Struct. Vol. 1, pp. 476-495, 2009
[11] V.M. Thakur, and P.D. Pachpor, Seismic Analysis of Multi-storeyed Building with TMD (Tuned Mass Damper), International Journal of Engineering Research and Applications, Vol. 2, Issue 1, 2012, 319-326, 2009

IS Codes

[12] IS 1893 (Part I): 2002, Indian Standard- Criteria for earthquake resistant design of structures, part 1 general provisions and buildings,
[13] Bureau of Indian Standards, New Delhi, June 2002.
[14] IS 875: 1987, Indian Standard code of practice for design loads (other than earthquake) for buildings and structure