"Seismic Behavior of Torsional & Mass Irregularity Due to Consideration of Tuned Mass Damper at Different Position of Building"

Reena Sahu
PG Scholar,
SSIPMT, Raipur
anurag.wahane@ssipmt.com

Pradeep Kumar Ghosh
Director,
UTD, CSVTU, Bhilai
pradeepkghosh8@gmail.com

Anurag Wahane
Research Scholar,
UTD, CSVTU, Bhilai
anurag.wahane@ssipmt.com

Sri Ram Krishna Mishra
Associate Professor,
Bhilai Institute of Technology, Raipur
rkmishra4776@gmail.com

Sanket Shrivastava
PG Scholar,
GEC, Jagdalpur
sanketshrivastava27@gmail.com

Article Info
Page Number: 9552 - 9559
Publication Issue:
Vol 71 No. 4 (2022)

Article History
Article Received: *15 September 2022*
Revised: *25 October 2022*
Accepted: *14 November 2022*
Publication: *21 December 2022*

Abstract
The study is to investigate the seismic behavior of RC building having tuned mass damper at the different position. The first phase of work is to analyze the RC building having mass damper at the center and random eccentric position of 5th, 7^{th,} and 9th Storey. The second phase of works is to validate the torsional and mass irregularity coefficient factor. Non-linear Time History Analysis is used for the identification of behavior of building. The seismic intensity of Zone -V is applied in the structure. The seismic response such as displacement, storey shear is been evaluated. The result shows that there is no torsional effect for the damper located at the center. Thus, concluded that for the structural safety of building, the damper should be placed centrally at the topmost storey.
Keywords: Tuned mass damper, Location, Center, Eccentric

1. Introduction

Lourenco et al. (2009) worked on the tuned damper pendulum based and the experiment is conducted to observe the advantage of pendulum damper over conventional dampers. The simulation study is done by considering the 3-D behavior of pendulum mass and found out that the change in the length of the cable will led to change in frequency of the damper. **Wirsching and Campbell (1974)** resolved the optimization of TMD parameter issue. The natural frequency and damping ratio problem is also solved by the author. The frequency mode responses have been investigated for the high-rise building having TMD. **Chouw et al. (2004)** worked on the two different locations of TMD by varying their natural frequency. The examining of soil interaction with Tuned dampers has been done. The seismic motion taken for the study is Northridge 1994 and its data is collected from SCG, NRG stations. It been concluded that there is significant difference due to effect of TMD between soil-structure interaction and ground motion. **Li et al. (2003)** examined the MAPTMD (multiple active-passive tuned mass damper numerically for the evaluation of performance which avoids ground motion of SDOF structure subjected to uniform frequency. It been concluded that the maximum frequency ratio of MAPTMD decreases with increasing mass ratio & increases with increasing mass ratio. **Farghaly and Ahmad (2012)** has studied the design and application of TMD. The case was such that the TMD was placed in top of the 10 storey building and has done investigation on it. The time history analysis examined the effect of structural response due to ground motions with and without TMD. As per analysis, it has been seen that the TMD location is one of the primary factors responsible of the reduction in responses such as displacement, storey forces of the building. **Luciara Silva Vellar et al. (2019)** suggested a new equation for the MTMD (multiple tune mass damper) location in lateral load building system and for their optimization of parameter. The methodology is suggested to establish the effectiveness in the ten-storey structure. The result shows that the suggested methodology will be very effective for the design of MTMD. **Mohsen Khazaei (2020)** investigate the two regular & irregular L-shaped and U-shaped steel frame building for the performance check of MTMD having 10 to 20 storey using recent ground motion records. The effect of MTMD in the seismic response is done by using NLTHA (Non-linear Time history analysis). The result shows that MTMD decreases the deformation of the structure and base shear up to 50 %. B.Islam and R.Ahsan (2012) determined the optimum TMD parameter to decrease the top storey response of the structure. using a operation algorithm. The data file of ground motion i.e. El Centro NS is carried out from COSMOS earthquake data bank. The result has developed an efficient approach in optimization in TMS parameters.

2. Research Objectives

The following objectives were considered for the work-

- ❖ Modelling of RCC Multistory building having tuned mass damper located at the center of 5th, 7^{th,} and 9th storey. Similarly, tuned damper located at eccentric point of 5th, 7^{th,} and 9th storey.
- ❖ To conduct spectrum analysis on the framed structures using existing primary data of time history having i.e., high intensity Corralito earthquake.
- ❖ To analyze seismic responses such as story shear and seismic weight for the considered building.
- ❖ To examine the acceptance criteria of mass coefficient factor.
- ❖ To identify the suitable location of tuned mass damper based on plan area and along the height of the building.

3. Planning Methodology of Seismic Analysis

The non-linear time history analysis has been done on the irregular model of building frames using ETABS software.

In this work, seismic analysis of asymmetry plan is been analyzed carried by Seismic Zone-V. There are about seven model examined for this study. The study comprises in two phase in which first phase involves positioning of TMD along the height of building at center and 2nd stage involves change in location of TMD along the height of building at eccentric point discussed in table 1. The responses which are to be evaluated are shear forces, maximum storey displacement and then compared for all the different cases.

Table 1: Proposing the Research Work

Description	Case ID Notations	
	Located at center of building	**Located at eccentric point of building**
Tuned Mass Damper at the fifth Storey	CTD5	ETD5
Tuned Mass Damper at the Seventh Storey	CTD7	ETD7
Tuned Mass Damper at the Ninth Storey	CTD9	ETD9
Reference Model (RM)	-	-

3.1 Structural Details

The residential area of asymmetry building taken are equal for all different cases. The building is of size i.e., 21.2 m X 28.4 m equal to 602 m^2 with a total (G+8) Storey. The floor-to-floor height is taken as 3.5 meters for all the structures and also the section properties is also common for all case frame structures. The following are the details of structural component which are used for design and analysis of the residential building.

Table 2: Member Properties & Specifications

Specifications		Values
Plan dimensions		21.2 m × 28.4 m
Column height		3.5 m
Typical Height of Building (G+8)		31.5 m
Beam Size		0.30 m × 0.5 m
Column Size		0.45 m × 0.60 m
Slab Thickness		0.150 m
Wall Thickness		0.200 m
Staircase	Rise	0.140 m
	Tread	0.300 m
	Width	1.5 m
	Stringer	0.150 m

3.2 Reference Model (RM)

The model used for the investigation is of H-shape which is irregular shape in nature. The purpose of this building is for residential cum-commercial. The grid lines are not equally spaced some are at distance 3.2 m c/c, some are at 3.6 m c/c, 5.2 m c/c. The building has stair at the left and right middle edge starting from top to bottom. The structure also comprises of tuned mass damper located at different location as per our considered study given in table 3.1.

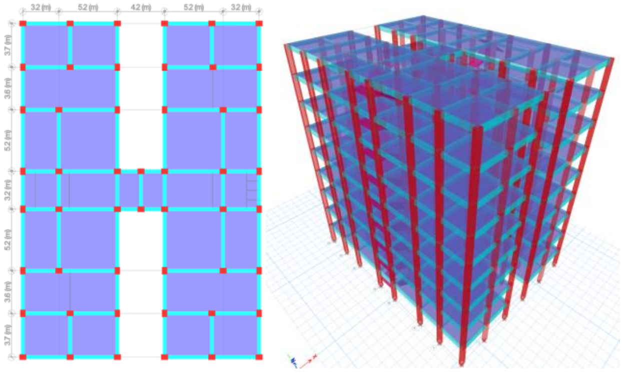
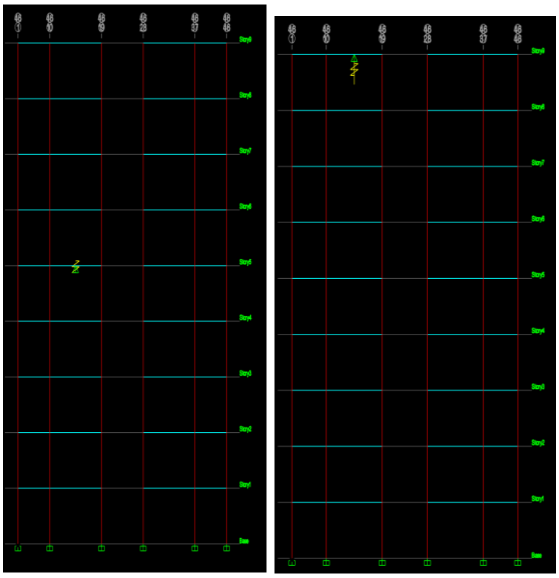


Fig. 1: Plan & Isometric view of G+8 Residential building model

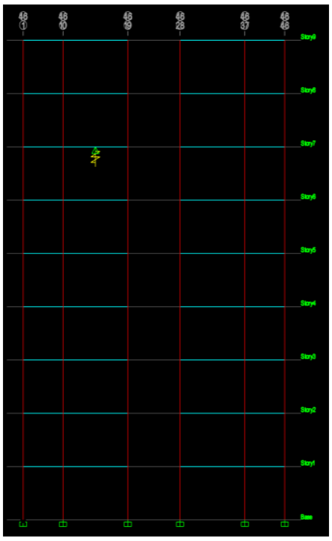
The model gridlines are like guidelines in making the model as per our requirements. Fig. 3.1 shows the spacing of gridline along both X and Y -direction for making H-shape model frame. The total height of building which is 31.4 m is under maximum limit as per IS 16700:2017 i.e., less than 80 m for rigid frame structure.

3.3 Model with TMD along the height of building Located at Eccentric Point

The reference model made is further modeled with tuned mass damper at different height of building which is shown in figure below. The eccentric point is located at distance 5.8 m along x-direction and 20.9 m along y-direction away from the left bottom corner of the building. Hence, the tuned mass damper is placed at (5.8, 20.9) coordinate from the left bottom corner of building as seen in figure below.



(a) ***(b)***



(c)

Fig. 2: Elevation View of Model frame (a) ETD5 (b) ETD9 (b) ETD7

3.4 Model with TMD along the height of building Located at Center

The reference model made is again modeled with tuned mass damper at different height of building which is shown in figure below. Here, the center is located at distance 10.5 m along x-direction and 14.1 m along y-direction away from the left bottom corner of the building. Hence, the tuned mass damper is placed at (10.5, 14.1) coordinate from the left bottom corner of building as seen in figure below. The model frame involved for such location are CTD5, CTD7 and CTD9 modeled simultaneously for the analysis and investigation.

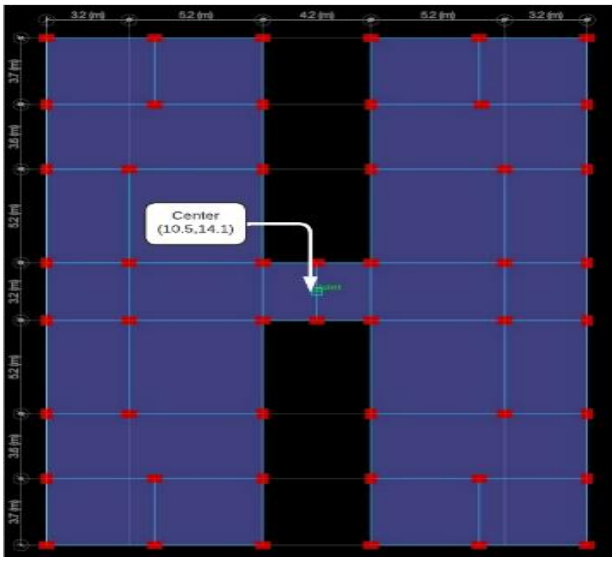


Fig. 3: Plan view of Model frame having TMD at Center Location of Different Storey

4.1 Displacement Report

The maximum value of displacement for ETD5 model along Corralito-1 direction is 16.67 mm at the top and 20.89 mm along Corralito-2 direction. The minimum displacement value along Corralito-2 direction is at Storey 5 i.e., 3.11 mm which is due to tuned damper at 5th storey. The non-linear plastic hinge formation and the ground motion is resulting accurate results of the case models as compared to linear dynamic analysis. For ETD5 model, the dispalcement versus time graph is given in figure 4.

4.2 Shear force Report

The storey force comprises of value of all the considered models along the storey and based on time-history steps wise for 40 seconds. The storey force has maximum cumulative at the base storey also known as Base Shear. The maximum value of storey force for ETD5 model along Corralito-1 direction is 2145.53 KN at the base and 2623.721 KN along Corralito-2 direction at base. The storey force value for the ground motion Corralito-1 and Corralito-2 along the both directions is given below. The maximum value of storey force for CTD7 model along Corralito-2 direction is 4385.79 KN at the base.

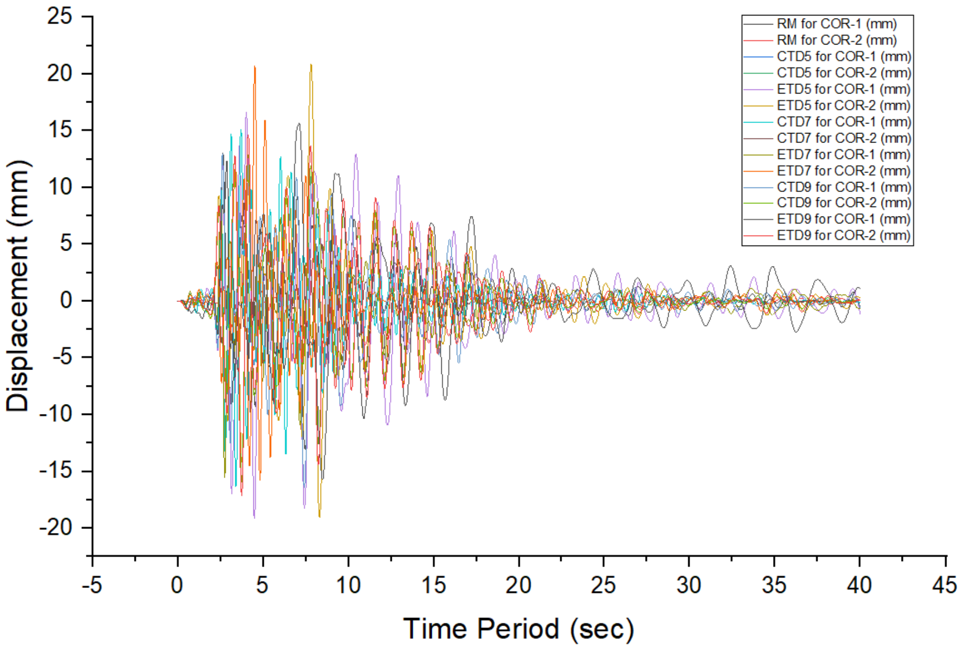


Fig. 4: Displacement V/s Time

x

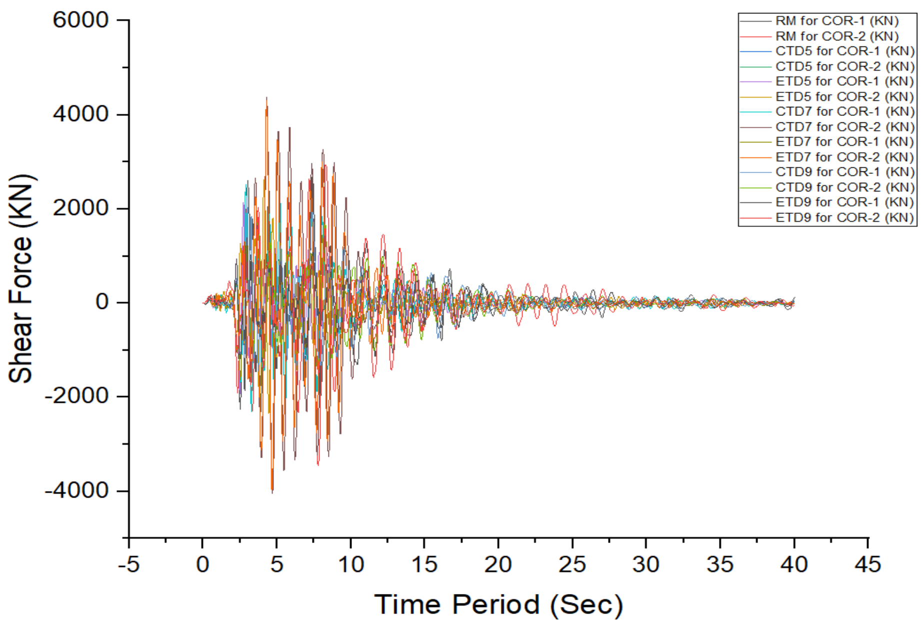


Fig. 5: Shear Force V/s Time

4.1 Mass Irregularity Report

Table 3: Mass Coefficient Factor

Case ID	Coefficient Criteria	Storey 9	Storey 8	Storey 7	Storey 6	Storey 5	Storey 4	Storey 3	Storey 2	Storey1
RM	**Mi / Mi-1**	NA	1.15	1.01	1.01	1.00	1.01	1.01	1.04	1.50
CTD 5	**Mi / Mi-1**	NA	1.16	1.02	1.01	1.01	2.32	1.01	0.98	0.86
ETD 5	**Mi / Mi-1**	NA	1.18	1.02	1.01	1.0	2.28	1.00	0.92	0.55
CTD 7	**Mi / Mi-1**	NA	1.17	1.00	2.35	1.01	1.01	1.02	1.06	1.59
ETD 7	**Mi / Mi-1**	NA	1.19	1.01	2.26	1.00	1.00	1.01	0.99	0.94
CTD 9	**Mi / Mi-1**	NA	2.17	1.02	1.01	1.00	1.00	0.99	0.93	0.61
ETD 9	**Mi / Mi-1**	NA	2.22	1.02	1.00	1.00	1.01	1.03	1.09	1.65

NA = Not Applicable

The criteria for mass irregularity are more than 2.0. Hence, the storey having less than 2.0 will be considered as mass irregularity. After careful examining of observations, for conventional RCC cases and building with tubed damper cases of building height is (G+8), the mass irregularity was for all the cases except normal building frame due to change in material properties and placing of heavy damper in ton.

5. Conclusions

The storey displacement for damper with center location along Corralito-1 direction is such that the CTD5 case exhibit minimum deflection at 5th storey, CTD7 shows minimum displacement at 7th storey and CTD9 shows minimum displacement at 9th storey. This shows that the application of dampers exhibits less displacement in the storey where damper is applied. After careful examining of observations, for all the cases having tuned mass damper at the center and eccentric location on both plan wise and storey-wise. It has been seen that mass irregularity were below the criteria limit i.e., 2.0 as per IS 1893:2016 for Reference model which donor have damper. Similarly, the building having damper were having mass factor above the criteria limit which is 2.32 > 2.0 (acceptable limit) for CTD5, 2.35 > 2.0 (acceptable limit) for CTD7 and 2.17 > 2.0 (acceptable limit) for CTD9. It been suggested that there should be avoidance of change in the column sizes and shapes along the building height or storey then mass irregularity would exist. Also, due to change in sectional and material properties of vertical member, stiffness irregularity may exist.

References

[1] Jerome J. Cannor "Introduction to structural motion control" Prentice Hall *Pearson Education, Inc., Upper Saddle River, New Jersey 07458*, Google books, Online resources www.scribed.com, *chapter 4 pp. 217-285.*

[2] Jerome J. Cannor and S. Laflamme "Structural motion engineering" doi 10.1007/978-3-319-06281-5__5, *Springer International Publishing Switzerland 2014, chapter 5 pp 199-277.*

[3] Pankaj Agrawal and Manish shrikhande "Earthquake resistant design of structures" Eastern economy edition, online resources www.phindia.com, *chapter 12 pp. 196-197&296.*

[4] S.K. Duggal "Earthquake resistant design of structures" Second edition, Oxford University Press, online resource www.oupinheonline.com, *chapter 5 pp. 202-203.*

[5] T. T. Soong and B. F .Spencer JR "Active, Semi active and Hybrid control of structures". *12 wcee 2000, 2834, pp. 2-5.*

[6] Islam B. and Ahsan R. (2012). "Optimization of Tuned Mass Damper Parameters Using Evolutionary Operation algorithm" *15 wcee, losboa 2012*.

[7] Padmabati Sahoo NIT Rourkela Orissa "Experimental and numerical study on tuned mass damper in controlling vibration of frame structure". Online resources www.ethesis.nitrkl.ac.in, *pp. 3-6.*

[8] **IS 1893 (Part I): 2002** Criteria for Earthquake Resistant Design of Structures. Part I General provisions and buildings (*Fifth revision*). Bureau of Indian Standards, New Delhi.

[9] **Etabs 2018** documentation.

[10] **IS 456: (2000)** Indian Standard Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi.

[11] **IS 875 (Part I): 1987** Code of Practice for Design Loads (Other than Earthquake) For Building and Structures.

[12] **IS 875 (Part II): 1987** Code of Practice for Design Loads (Other than Earthquake) For Building and Structures.

[13] Lin, Chi-Chang, et al. "Vibration control of seismic structures using semi-active friction multiple tuned mass dampers." Engineering Structures 32.10 (2010): 3404-3417.

[14] Lourenco, R. , Roffel , A. J. and Narasimhan 2009 "Adaptive pendulum mass damper for the control of structural vibrations" *Cansmart* 2009 international workshop smart materials and structures 22 - 23 October 2009, *montreal, quebec, Canada*.

[15] Alexander Nicholas, A. and Schilder Frank 2009 "Exploring the performance of nonlinear tuned mass damper" *Journal of Sound and Vibration 319 pp. 445–462.*

[16] Wong K.K.F(2008) "Seismic Energy Dissipation of Inelastic Structures with Tuned Mass Dampers *"Journal of Engineering Mechanics, Vol. 134, No. 2 77) .*

[17] Saidi, I. Mohammed, A. D. and Gad, E. F. 2007 "Optimum Design for Passive Tuned Mass Dampers Using Viscoelastic Materials" *Australian Earthquake Engineering* Society *2007 Conference.*

[18] Molla, J. P., Dhabliya, D., Jondhale, S. R., Arumugam, S. S., Rajawat, A. S., Goyal, S. B., . . . Suciu, G. (2023). Energy efficient received signal strength-based target localization and tracking using support vector regression. Energies, 16(1) doi:10.3390/en16010555s

[19] Kwok, K.C.S. and Samali, B. 2006 "Performance of tuned mass dampers under wind loads" *Engineering Structures, Vol. 17, No. 9, pp. 655~67, 1995.*

[20] Chouw, Nawawi 2004. "Behaviour of soil-structure system with tuned mass dampers during near-source earthquakes" *13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, August 1-6, 2004, Paper No. 1353.*

[21] Raghavendra, S., Dhabliya, D., Mondal, D., Omarov, B., Sankaran, K. S., Dhablia, A., . . . Shabaz, M. (2022). Development of intrusion detection system using machine learning for the analytics of internet of things enabled enterprises. IET Communications, doi:10.1049/cmu2.12530

[22] Ghosha, A. and Basu, B. 2004 "Effect of soil interaction on the performance of tuned mass dampers for seismic applications" *Journal of Sound and Vibration 274 (2004) 1079–1090.*

[23] Samali, Bijan and Al-Dowod, Mohammed 2003 "Performance of five-story benchmark model using an active tuned mass damper and fuzzy controller" *Engineering Structures 25 (2003) 1597–1610.*

[24] Li, Chunxiang and Liu Yanxia 2002. "Active multiple tuned mass dampers for structures under the ground acceleration" *Earthquake engineering and structural dynamics earthquake 2002; 31:1041–1052.*