Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(10) (2021) 625-628
DOI: 10.22060/ceej.2019.15584.5959

Comparing performance of TMD and MTMD vertically distributed in height for multi-modal seismic control of tall buildings

Ali Akhlagh Pasand[1], Amirhosein Fatollah pour[2], Seyed Mehdi Zahrai[3,*]

[1] MSc student of Earthquake Engineering, University of Tehran, Tehran, Iran
[2] MSc student of Structural Engineering, University of Zanjan, Zanjan, Iran
[3] Professor, School of Civil Engineering, College of Engineering, University of Tehran, Tehran, Iran

ABSTRACT: Nowadays, vibration control in civil engineering is commonly used. Tuned mass damper (TMD) is one of the simplest and most reliable control instruments, which consists of a mass, spring, and damper. TMDs are usually set to the frequency of the first mode of the structure. The sensitivity of the TMD to the changes of structure's frequency is considered as the weaknesses of this controlling system, and the lack of adjustment of the damper's parameters to its optimum state or the changes in the structure's frequency leads to the inefficiency of the system. The non-linear behavior of the structure is an example of changing the natural frequency of the structure during vibration. In this study, to investigate and compare the performance of the single mass damper in the maximum modal displacement (roof) and multiple mass dampers vertically distributed in the height of the structure, based on the modal analysis, two linear and nonlinear models of a 40-story structure were selected. The structure has been modeled in OpenSees software using seven earthquake records. The analysis results for applied earthquakes under the maximum acceleration of 1.0g show that the control of the linear structure by multiple tuned mass dampers (MTMDs) tuned to the first and second modes have more appropriate behavior than others, and the average reduction of the maximum displacement of the roof applying this type of dampers is 14.5%, which is about 2 times more than reduction of the STMD tuned to the first mode and the MTMDs tuned to the first or second modes, systems. However, due to the assumption of tuning the design parameters of the dampers corresponding to their elastic behavior, the performance of single and multiple mass dampers slightly decreases in a nonlinear model of the structure while structural responses are still controlled. Also, for the 10% error caused by misadjusting of the dampers, the behavior of MTMDs is more appropriate.

Review History:

Received: 2019-01-06
Revised: 2019-01-06
Accepted: 2019-07-11
Available Online: 2019-07-11

Keywords:

Single tuned mass dampers (STMD)
multiple tuned mass dampers (MTMD)
passive control, dynamic time-history analysis
modal analysis

INTRODUCTION

Tuned Mass Damper (TMD) is a passive control tool consisting of a mass, a spring and a damper, which transfers the energy from main structure to itself. Performance of a Single Tuned Mass Damper (STMD) is sensitive with regard to changes in frequency and damping, leading to problems such as weakness in tuning frequency or non-optimality of damping. On the other hand, in tall structures considering the heavy weight of the structure, the mass needed for the damper will increase and more space will be required for placement in the structure and sometimes, to place the required mass for the damper, this space will include some floors. To deal with this issue, using Multiple Tuned Mass Damper (MTMD) is recommended.

The concept of a mass damper was first proposed by Frahm [1] in 1909. Following that, researchers sought for a way to fix the issues regarding STMD and they recommended and investigated distribution of TMDs in different places. Researchers such as Wu and Chen [2] in 2000 and Chen and Wu [3] in 2001 studied the effects of distributed TMDs based on acceleration of main structure in modal response of a 6-story structure to show the operation of the dampers under seismic load. In 2009, Petit et al. [4] proposed the best place based on the best shift in structure's frequency from resonance force frequency. In 2010, Moon [5] concluded that mass damper, when distributed among the structure's height and based on mode shapes, shows better performance.

In 2013, Farshidianfar and Soheili [6], using Ant Colony Optimization (ACO) and in order to reduce maximum displacement and acceleration in floors, found optimal parameters for TMD in high-rise buildings by considering soil and structure interaction. In 2017, Elias et al. [7] studied multimode seismic control of a 20-story benchmark structure using multiple mass dampers distributed based on mode shapes in the floors. In 2018, Bayat et al. [8] investigated the performance of a multiple mass damper distributed in height with a mass - spring model of a 4-story structure under acceleration records of three actual earthquakes.

This article works on the effect of using distributed

*Corresponding author's email: mzahrai@ut.ac.ir

MTMD in a tall structure against seismic load, while most of the previous studies focused on studying distribution of this damper in one floor (usually roof) or its distribution in height based on maximum displacement of each mode against wind load.

Specifications of Case Study Structure

The investigated structure in this study is a 40-story structure modeled as a 2D mass-spring model.

Mass Dampers Design Parameters

Optimal values for damping ratio and damper frequency are taken from those provided by Pastia and Luca [9] which, in fact, are relations used for optimizing STMDs against harmonic load and are employed for such purpose. Using these relations, design parameters for dampers such as their mass, stiffness and damping, assuming an elastic behavior, are determined:

$$f_{TMD} = \frac{f_1}{1+\mu} \quad (1)$$

$$\xi_{opt} = \sqrt{\frac{3\mu}{8(1+\mu)}} \quad (2)$$

Where, f_{TMD} is damper frequency, f_1 is structure main frequency, μ is mass ratio, equal to 1% of modal mass of the structure and ξ_{opt} is the optimal damping ratio of the damper.

Positioning of MTMDs

In order to design multiple mass dampers, a number of mass dampers with identical specifications are used. So, to calculate design parameters, first the positions and their numbers are determined and then, dampers are designed based on the considered mode(s).

Determining position of the dampers and number of them are obtained based on modal analysis of structure according to Fig. 1. In this method, in floors with modal displacement above 0.5, a damper is used.

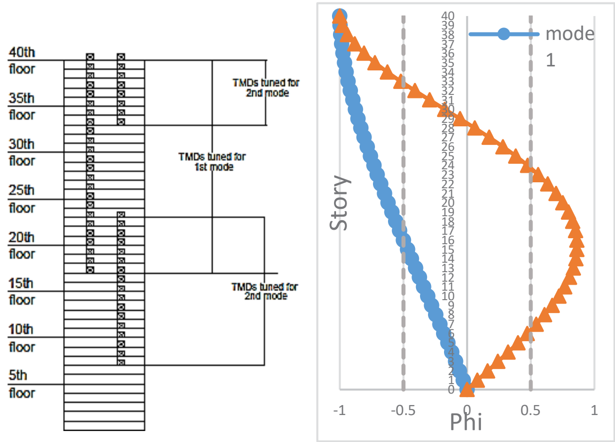

Fig. 1 Determination of the number and position of mass dampers according to mode shapes

CONCLUSION

Single and multiple mass dampers for a 40-story structure were used to improve structure responses. In order to investigate the results, the average roof displacement and average base shear of the structures in different modes were compared under 7 earthquakes.

Average roof displacement results for 7 earthquakes indicated that, in linear model of the structure, MTMDs for the 1st and 2nd modes represent most appropriate behavior than others and average structure displacement using these types of dampers has reduced 14.5 percent which is about 2 times of the decrease due to using STMDs for the 1st mode and MTMDs for the 1st or 2nd modes. Also, results for maximum displacement in the Northridge earthquake of Beverly Hills station shows that, due to decrease in RMS values, using mass dampers have resulted in stability in structure's performance. It also can be seen that in this earthquake, MTMD for the 1st and 2nd modes has the most decrease of maximum displacement and RMS. Performance of dampers in decreasing nonlinear model response of the structure, assuming elastic behavior in tuning their design parameters, has changed 22 percent on average, so that STMD for the 2nd mode, STMD for the 1st mode and MTMD for the 1st and 2nd modes have the best performance with 8.8, 8.4 and 8.1 percent decrease in average structure responses under 7 earthquake records respectively and MTMD for the 2nd mode and MTMD for the 1st mode performed worst with 5.9 and 7.6 percent decrease in average structure responses, respectively. As the structure enters nonlinear region and due to mass dampers being out of tune, STMD for the 1st mode and MTMD for the 1st and 2nd modes have the best performance with 1.4 and 0.8 percent decrease in average base shear, respectively.

REFERENCES

[1] H. Frahm, Device for damping vibrations of bodies, US989958A Patent, 1911.

[2] J. Wu, G. Chen, Optimization of multiple tuned mass dampers for seismic response reduction, The American control conference,, Chicago, Illinois (IL), USA 2000, pp. 519-523.

[3] G. Chen, J. Wu, Optimal placement of multiple tuned mass dampers for seismic structures, Journal of Structural Engineering, American Society of Civil Engineers (ASCE), 127(9) (2001) 1054-1062.

[4] F. Petit, M. Loccufier, D. Aeyels, On the attachment location of dynamic vibration absorbers, Journal of Vibration and Acoustics, American Society of Mechanical Engineers (ASME), 131(3) (2009) 1-8.

[5] K.S. Moon, Vertically distributed multiple tuned mass dampers

in tall buildings: Performance analysis and preliminary design, The Structural Design of Tall and Special Buildings, 19(3) (2010) 347-366.

[6] Farshidianfar, S. Soheili, Ant colony optimization of tuned mass dampers for earthquake oscillations of high-rise structures including soil–structure interaction, Soil Dynamics and Earthquake Engineering, 51 (2013) 14-22.

[7] S. Elias, V. Matsagar, T.K. Datta, Distributed tuned mass dampers for multi-mode control of benchmark building under seismic excitations, Journal of Earthquake Engineering, (2017).

[8] Bayat, Beiranvand, P. and Ashrafi, H.R., Vibration control of structures by multiple mass dampers, Jordan Journal of Civil Engineering, 12(3) (2018) 461-471.

[9] C. Pastia, S.G. Luca, Vibration control of a frame structure using semi-active tuned mass damper, Buletinul Institutului Politehnic din lasi. Sectia Constructii, Arhitectura, 59(4) (2013) 31.

HOW TO CITE THIS ARTICLE

A. Akhlagh Pasand, A.H. Fatollah Pour, S.M. Zahrai, Comparing performance of TMD and MTMD vertically distributed in height for multi-modal seismic control of tall buildings, Amirkabir J. Civil Eng., 52(10) (2021) 625-628.

DOI: 10.22060/ceej.2019.15584.5959