

Multi-Tuned Mass Dampers for Seismic Response Reduction of Mid and High-Rise Buildings

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Abstract

The purpose of this study is to investigate the effectiveness of multi-tuned mass dampers on reduction of acceleration and RMS acceleration of mid and high-rise buildings. Two 16 and 32 story buildings are designed according to Iranian code. The buildings are analyzed under the time history records of Bam and Zarand earthquakes. Two TMDs are specified for the structures. The first TMD is placed on the top and the other is located somewhere at the middle stories. Numerical results show that the multi-tuned mass dampers reduce the acceleration of middle stories by 10-15% more than a single TMD. Time history analyses also indicate that the multiple mass dampers weighing 6% to 8% of the total structure weight with uniform distribution on the stories of the structures decrease acceleration. These reduction is about 15-30% for acceleration and RMS acceleration in comparison with those of uncontrolled structure.

Keywords: Multi-tuned mass dampers, Time history analyses, acceleration and RMS acceleration reduction

1. INTRODUCTION

A tuned mass damper is a passive control device consisting of a lumped mass with a spring and viscous damper attached properly to the main structure to reduce any undesirable vibration of the system. Recently systems with multiple tuned mass dampers have been proposed. In these systems each TMD is tuned to a different natural frequency of the structure, see Figure 1.



Figure 1. Multiple tuned mass dampers



2. MULTI PLE TUNED MASS DAMPER (MTMD)

A system with multiple tuned mass dampers consists of two lumped mass dampers. The first TMD is placed on the top of the structure and is tuned to the first natural frequency of the structure, and the second one is placed somewhere at the middle stories and is tuned to the second natural frequency of the main structure.

3. STRUCTURAL MODEL

For the purpose of time history analysis two 2-D concrete frames including of a 16 and 32 story buildings are defined. These buildings are designed according to ACI code. Two base excitations are used to evaluate the effectiveness of the control system. Bam and Zarand records are shown in the figures 2 and 3 respectively.



Figure 2. Bam earthquake record



Figure 3. Zarand earthquake record

3. EVALUATION CRITERIA

In this study, maximum acceleration and root mean square (RMS) of acceleration are used to compare the response of structures with and without MTMDs. The RMS of acceleration shows the variation of acceleration during the earthquake.



4. UNCONTROLLED STRUCTURE

Figure 3 and 4 show the typical results of maximum acceleration and RMS acceleration at each story of the uncontrolled structures. Two recorded ground motion were used as the input motions, namely Bam and Zarand which are considered as near field earthquake. These figures show that the maximum acceleration of building occurs at the top of the buildings.



Figure 4. Maximum acceleration of uncontrolled structures under scaled earthquake records



Figure 5. RMS acceleration of uncontrolled structures under scaled earthquake records



4. NUMERICAL RESULTS

Figure 6 to 9 show the reduction of acceleration and RMS acceleration for 16 and 32 story building under scaled earthquake records of Bam and Zarand for three different control cases.



Figure 6. Percentage of reduction of acceleration and RMS acceleration under Bam earthquake records (16-story)



Figure 7. Percentage of reduction of acceleration and RMS acceleration under Zarand earthquake records (16story)





Figure 8. Percentage of reduction of acceleration and RMS acceleration under Bam earthquake records (32-story)



Figure 9. Percentage of reduction of acceleration and RMS acceleration under zarand earthquake records (32story)



In the figures above three control cases are defined. In the first case (S-TMD), a single tuned mass damper is placed on the top of the structures. The mass ratio and damping ratio of damper is 0.06 and 0.1 respectively. The damping ratio of the main structure is also 0.05. TMD has been tuned to the first natural frequency mode of the structures. The second case is N-MTMD where a tuned mass damper is placed at the top floor with mass ratio of 0.05, and the second TMD is placed on the 15 and 31 stories for 16 and 32-story structures with mass ratio of 0.01. The damping ratio of both TMDs is 0.1. The first TMD has been tuned to the first natural frequency mode of the structures, while he second TMD is tuned to the second natural frequency mode of the structures which is dominant frequency of the earthquake records. The third control case (U-MTMD) is similar to the second one, but the mass is distributed uniformly between the top and middle floors, i.e. the mass ratio is 0.03.

5. CONCLUSIONS

Numerical result revealed that the MTMD are able to decrease the acceleration of the uncontrolled structures much better than S-TMD. Having MTMD instead of S-TMD increased the robustness of the systems, demonstrated by the reduction of structural responses for various input motions. Based on this study, some conclusions can be drawn as follows:

- 1. The N-MTMD are more effective in suppressing the acceleration at upper floors, while the U-MTMD decrease the acceleration of middle stories much better than S-TMD and N-MTMD.
- 2. MTMD are more robust and each occupies a much smaller space for installation.
- 3. N-MTMD can mitigate the acceleration and RMS acceleration at upper stories by 10% more than a conventional single TMD.
- 4. U-MTMD suppresses the acceleration and RMS acceleration of middle stories 10-15% more than a single TMD, while increases the acceleration at upper stories in comparison with N-MTMD.

This study focused on the acceleration reduction with MTMD. It is important that the MTMD do not appear advantageous over a conventional TMD for displacement control.

6. **REFERENCES**

- 1. Chen, G., and Jingning, W. (2001), "Optimal placement of multiple tuned mass damper for seismic structures," ASCE, Journal of structural engineering 121(9), pp 1054-1062.
- 2. Okhovat, M. R., Rahimian, M., and Ghorbani-Tanha, A. K. (2006), "Tuned mass damper for seismic response reduction of Tehran tower," 4th International Conference on Earthquake Engineering Taipei, Taiwan (Paper No.132).
- 3. Reinhorn, A. M., (2004), "Structural Control: An Introduction to Passive, Active and Hybrid Systems," http://civil.eng.buffalo.edu/technion.
- 4. Connor, J. J., (2000), "Introduction to Structural Motion Control," Massachusetts Institute of Technology, USA.