Advanced Science and Technology Letters
Vol.69 (Architecture and Civil Engineering 2014), pp.1-4
http://dx.doi.org/10.14257/astl.2014.69.01

Control Performance Evaluation of Shared Tuned Mass Damper

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Abstract. In this study, control performance of a shared tuned mass damper (STMD) for seismic response reduction of adjacent buildings has been evaluated. To this end, two 8-story example buildings were used as example structures. Multi-objective genetic algorithm has been employed for optimal design of the stiffness and damping parameters of the STMD. El Centro (1940) and Kobe (1995) earthquakes were used for structural analyses. Based on numerical analyses, it has been shown that a STMD can effectively control dynamic responses and reduce the effect of pounding between adjacent buildings subjected to earthquake excitations in comparison with a traditional TMD.

Keywords: Shared tuned mass damper, Vibration control, Adjacent buildings, Pounding effect, Multi-objective genetic algorithms, Optimal design.

1 Introduction

Because tall buildings are recently constructed closely in big cities, the effect of pounding between adjacent buildings increases. Pounding means collision of buildings or different parts of the building during vibration. When building heights are different, the roof of the smaller building may pound at the mid height of the taller one, it is very dangerous. In order to mitigate pounding and reduce vibrations of adjacent structures, a lot of research has been performed [1-3]. Most of them focused on coupled building control strategies for reducing dynamic responses of damper-connected adjacent buildings. Although a tuned mass damper (TMD) is one of the most widely used and accepted response control systems for tall buildings, it is not frequently used to reduce the effect of pounding between adjacent tall buildings. Abdullah et al. [4] presented that a shared tuned mass damper (STMD) provided effective control performance for vibration and pounding in adjacent structures. Because the STMD is connected to both buildings, the problem of tuning the STMD stiffness and damping parameters becomes an issue. In their study [4], a design procedure utilizing a performance function is proposed to obtain the STMD parameters to result in the best overall system response. No other study about a S

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ISSN: 2287-1233 ASTL
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TMD except this research has been reported to date. Control performance of a STMD for adjacent tall buildings subjected to seismic excitation was investigated and optimal design procedure for the STMD parameters was proposed using multi-objective genetic algorithms in this paper.

2 Adjacent Building Model with STMD

Two 8-story example building structures shown in Fig. 1 are employed to investigate control performance of a STMD system. The masses of each floor of building A and B are 3.5×10^5 kg and 4×10^5 kg, respectively. The inter-story stiffnesses of building A and B are 3.404×10^8 N/m and 6.127×10^8 N/m, respectively. The damping coefficient of each story for both buildings is 1.0×10^5 N/m/s. The first five natural periods of the building A are 1.09, 0.37, 0.23, 0.17 and 0.14 sec. Those of the building B are 0.87, 0.29, 0.18, 0.13 and 0.11 sec.

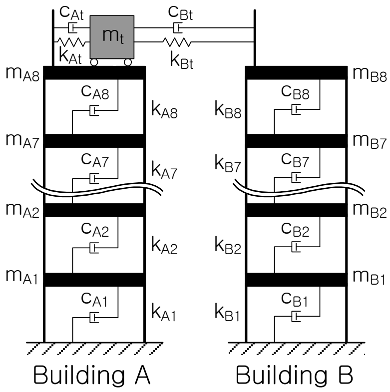

Fig. 1. Configuration of STMD

For comparison purpose, control performance of conventional TMD for each building was investigated. The mass ratio of TMD with respect to the story mass is set to be 15% in each building. That is, the TMD masses for building A and B are 5.25×10^4 kg and 6.0×10^4 kg, respectively. Average value of TMD masses for building A and B is used for the STMD mass, i.e., 5.625×10^4 kg. Optimal parameters presented by Warburton [5] are used for design of conventional TMD.

3 Optimal Design of STMD

Because both dynamic responses of building A and B cannot be simultaneously minimized, the design procedure of the STMD can be thought of as a multi-objective process that finds optimal solutions that show superior control with respect to several

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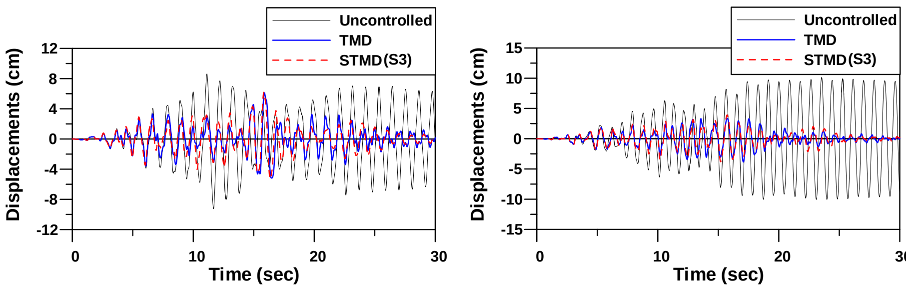
performance indices. Therefore, multi-objective genetic algorithm (MOGA) is employed in this study for optimal design of the STMD. The reduction of both the top floor displacement responses of building A and B are used as two objective functions for this multi-objective optimization problem. Each response controlled by the MOGA-optimized STMD is normalized by the corresponding response of the building with the conventional TMD system in each objective function.

4 Control Performance of STMD

The MOGA based optimization is performed with the population size of 100 individuals. An upper limit on the number of generations is specified to be 1000. As the number of generations increases, the control performance of the elite (i.e. non-dominated) individuals is improved. After optimization run, Pareto-optimal front (a set of Pareto-optimal solutions) is obtained. Among the Pareto optimal solutions, three optimal designs (S1, S2, S3) for the STMD has been selected. Here, S1 and S2 show optimal control performance for Building A and B, respectively. S3 can appropriately control both responses of Building A and B.

El Centro (1940, NS), Mexico (1985, NS) and artificial earthquake records are used for numerical simulation to investigate the control performances of the STMD and TMD. The top floor displacement time histories of Building A and B with TMD and STMD are presented in Fig. 2. As can be seen in the figure, displacement responses controlled by TMD are much smaller than those of the uncontrolled buildings. The STMD can provide very similar control performance as the TMD system. It should be noted that the STMD uses only half mass compared to the conventional TMD system.



(a) Building A (b) Building B

Fig. 2. Top floor displacements of artificial earthquake

When a building oscillates during an earthquake, adjacent buildings either move towards each other or away from each other. Peak relative displacements between top floors of two example building structures subjected to artificial earthquake are presented in Table 1. As the relative displacement increases, the possibility of pounding of adjacent buildings increases. Peak relative displacement of the uncontrolled buildings subjected to Kobe earthquake, which is the most strong ground

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motion out of three example earthquakes, is 105.4 cm. It can be reduced by more than 50% (i.e. 58.2 cm) when TMD is used. All STMDs shown in Table 1 can provide better control performance in reducing pounding effects between adjacent buildings compared to TMD system.

Table 1. Peak relative displacement of top floor (cm).

Earthquake	Artificial	El Centro	Kobe
Uncontrolled	16.7	60.3	105.4
TMD	7.0	20.5	58.2
STMD (S1)	4.7	18.7	48.3
STMD (S2)	4.9	19.3	47.9
STMD (S3)	5.1	17.9	44.9

5 Conclusions

The control performance of a shared tuned mass damper for adjacent tall buildings subjected to earthquake excitation has been evaluated in this study. Multi-objective genetic algorithm was used for optimal design of STMD. Based on numerical simulations, it can be seen that the STMD shows similar control performance as the TMD although the STMD uses only half mass compared to the conventional TMD system. The STMD can reduce relative displacement between two example buildings more effectively in comparison with the TMD. It is expected that the STMD is an effective means for mitigating the pounding effect of adjacent tall buildings.

Acknowledgements. This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (NRF-2013R1A1A2058312).

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