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Semi-active control of structures with MR and Orifice dampers subjected to underground blast-induced vibration

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ABSTRACT: Using the control tools is an efficient method to decrease the responses of the structure under external excitations. In this regard, this study investigates the performance of two structures equipped with MR dampers and Orifice dampers under blast-induced vibration. In addition to stimulating the underground blast-induced vibration (due to the different nature of these loads), seismic excitation has also been used to evaluate the efficiency of these dampers. These dampers are semi-active devices, which change the output force of the damper by changing the input voltage and magnetic field of dampers. Also, in this paper, clipped-optimal algorithm was used. This algorithm can generate optimal damper force by changing the voltage at each time step based on the input forces. In this research, structural responses based on optimal and maximum voltage are considered. Also, the numerical results of the structure are compared with LQR algorithm. The LQR algorithm is considered a criterion for reducing structural responses to blast-induced vibration. The results indicate that the proposed method (the different locations and types of dampers) is efficient for decreasing the responses of the structure.

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1- Introduction

In recent years, the importance of using methods that leads to reducing the damage in the structures caused by earthquakes, blast excitations, etc. has become more apparent. Blast excitation is one of the important loads that has very high energy in a short period of time. This type of excitation can cause much more damage to structures than an earthquake [1, 2].

There are many control strategies that can help to reduce the destructive effects of different excitations. The semi-active control strategy is one of them that can be efficient. In this field, MR damper and Orifice damper are two types of dampers that have attracted a lot of attention in recent years. Also, the Clipped-optimal is used to find an appropriate reduction in responses of buildings [3-5].

Some researchers considered the effects of the blast excitations on the buildings. Mondal et al. [1] studied the responses of a structure equipped with base isolator under blast excitation. Results of this study indicate that this strategy is highly effective in decreasing responses of structure. Also, Chakraborty and Chaudhuri [2] studied the responses of a three-story structure under the blast excitations by using the active control strategy. Due to the higher energy consumption of this method compared to other methods, this strategy has reduced the responses of the structure.

In this study, the performance of the two types of dampers under blast excitation has been investigated. Blast excitation has been selected in this research due to its different nature compared to common earthquake excitations. For decreasing the destructive effects of this type of excitation and to find the optimum responses, MR damper and Orifice damper are located on different floors. Also, in order to achieve an efficient control force, the clipped-optimal strategy is used.

2- Methodology

In this study, two structures using two types of semi-active dampers are used. MR damper and Orifice damper are located on different floors in order to achieve optimal responses. MR damper modeled by using modified bouc-wen. The main control strategy of this research is clipped-optimal. In the clipped-optimal control strategy, the voltage applied to MR damper and Orifice damper is increased to the maximum level, When the desired optimal force is bigger than produced force and the two forces are the same sign. Otherwise, the voltage applied is set to zero. This control strategy obtains the optimum control force by using LQG control algorithm (Figure 1). Also, the maximum voltage strategy is used.

In order to investigate the effectiveness of this control strategy, two shear structures are chosen. In other words, three-story buildings and five-story buildings are considered.

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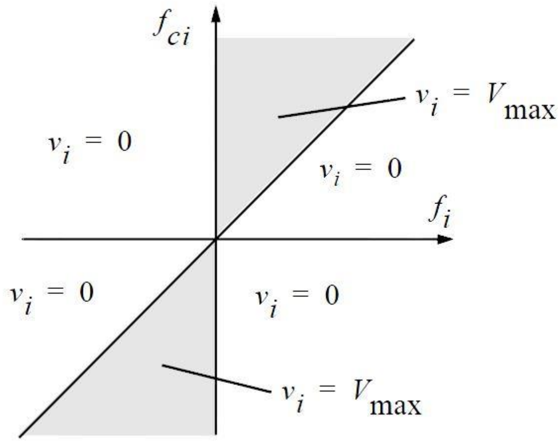

Fig. 1. Diagram of applied voltage [6]

The dampers in the three-story building are placed in two cases. In the first place, the damper is located only on the first floor and in the second place, in order to appropriate reduction of the responses of the structure under the two kinds of excitations, the dampers are placed in all the floors. Also, in the five-story building, three cases are investigated. In this building, dampers are located on two first floors, two last floors and all floors.

Blast excitation is modeled by assuming 10 tons of TNT and 50 meters from the structure. This type of loading is considered for finding the critical responses of structures. This excitation is modeled as follows:

$$\ddot{x}_g(t) = -(1/t_d)\bar{\dot{x}}_g \exp(-t/t_d) \quad (1)$$

Table 1. Parameters of the blast excitation

R(m)	$C_p (m/\sec)$	$PPV\ (\bar{\dot{x}}_g)(m/\sec)$	$\ddot{x}_g (m/\sec^2)$
50	5280	0.2266	23.928

In this equation, the acceleration of blast excitation is modeled based on the characteristics of soil, distance and amount of TNT. The considered parameters for modeling the blast excitation are presented in Table 1. In this table, C_p is assumed 5280 m/sec based on the existing soil. Also, an earthquake record is chosen to better comparison of responses.

3- Results and Discussion

Based on the chosen structures and excitations, different kinds of arrangements of dampers are located on two structures. In other words, five types of arrangement are examined. Based on the responses of structures, the semi-active method cannot decrease all responses of structures, but this control strategy can lead to optimum responses by using the dampers in all floors of two structures. The acceleration of the fifth floor of the structure under the blast excitation can show the effectiveness of chosen strategy (Figure 2).

But using the damper on the first floor of the three-story building and using two dampers in the five-story building is not effective in some responses of structure. These responses are expected due to the different nature of blast excitation rather than earthquake excitation. Of course, in all cases, the structures have experienced a suitable reduction under the excitation.

4- Conclusion

In this research, the responses of two buildings under the blast excitation are considered. In order to reduce the responses of structures, MR damper and Orifice damper

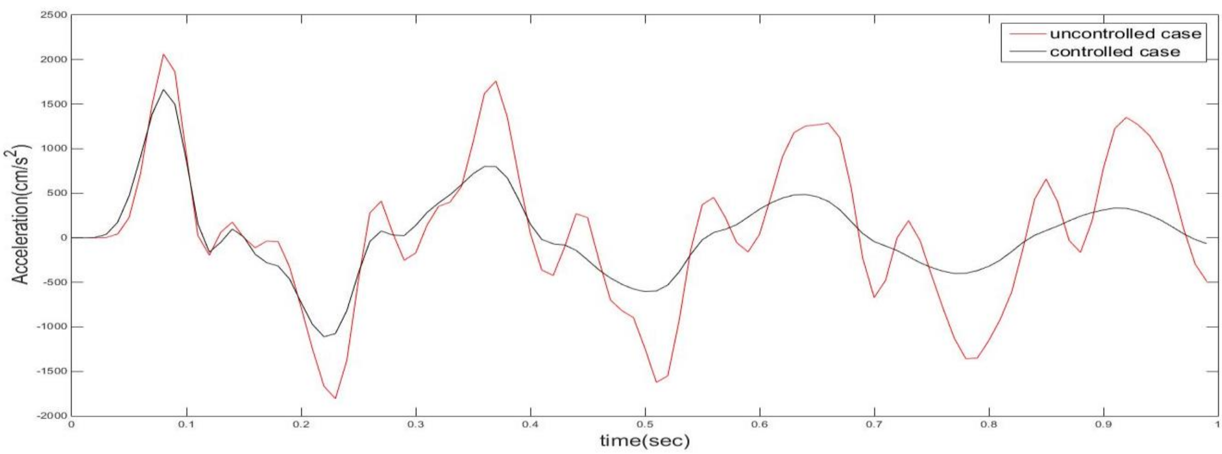

Fig. 2. Acceleration responses of the fifth floor of the structure under the blast excitation by using MR damper in two first floors

are used. For finding the control force of these dampers, the clipped-optimal control strategy is used. Also, the maximum voltage strategy is utilized. In addition to the blast excitation, the earthquake excitation is used. According to the investigation of 5 cases of placement of dampers in two structures, in the cases where the dampers are not placed on all floors, the responses of structures have not decreased in most floors. Of course, when the dampers are located on all floors, all responses of the blast excitation have been properly reduced.

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