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Seismic response analysis of coupled building involving MR damper and elastomeric base isolation

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Abstract Application of control devices for seismic hazard mitigation has emerged as an attractive and viable proposition over the years. Buildings in close proximity are prone to pound to each other, under seismic excitation. It has been observed during past earthquakes that pounding in adjacent buildings has caused significant structural damage. To meet this challenge, application of control devices has been investigated by researchers, under various coupled building control strategies.

The present study investigates the comparative performance of three proposed schemes of coupled building control involving Magnetorheological (MR) damper and elastomeric base isolation, named as, Semiactive, Hybrid 1 and Hybrid 2. The results of numerical study showed that Hybrid controls are more effective in controlling the response as compared to Semiactive control. Further, influence of device parameters on control performance has been investigated through a parametric study.

1. Introduction

Large scale damage of closely spaced building due to mutual impact, under seismic excitation has been observed during past major earthquakes, such as, Imperial Valley, 1940, Kobe, 1994 and Bhuj, 2001. Application of control devices for earthquake hazard mitigation for closely spaced buildings has been investigated by researchers through 'coupled building control', under which adjacent buildings are connected through supplemental energy dissipating devices. The coupled control schemes render dual advantage of avoiding pounding along with response reduction; moreover control devices to control the response can be fixed in gap between two close buildings.

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Researchers have been investigating the effectiveness of various semiactive, and passive devices for response reduction under earthquake excitation. Amongst various passive devices, base isolation has proved to be a time tested approach for seismic hazard mitigation of structures. Jangid and Datta [1] presented an updated review on behaviour of various base isolated systems, applied to the buildings subjected to seismic excitation. Su et al. [2] studied the comparative performance of different isolation devices and found that superstructure acceleration is controlled at the expense of bearing displacement and vice versa. Further, the study noted that elastomeric bearings are very effective in controlling the response of structures subjected to earthquake excitations. An analytical study, examining the performance Lead Rubber Bearing, in controlling the response of elevated liquid storage tank was carried out by Shrimali and Jangid [3], which showed that the isolation system is effective in response mitigation. Providakis [4] carried out an analytical study to figure out the effectiveness of Lead Rubber Bearings (LRBs), in terms of base displacement and drift of the superstructure.

Semiactive control devices have emerged as a very attractive proposition for the seismic response mitigation of civil engineering structures, owing to inherent advantages of being adaptable, stable and having very low power requirement, Symans and Constantinou [5]. Housner et al. [6] observed that Hybrid control strategies are the most powerful technique for the mitigation of earthquake induced structural damage.

In terms of installing the control devices, researchers have been employing various schemes, amongst which, interconnection of adjacent buildings through control devices/dampers, called 'coupled control', have also been explored. In 'coupled building control', two dynamically dissimilar, adjacent buildings are connected through supplemental energy dissipating devices.

Westermo [7] devised a technique to connect buildings in cluster to reduce the pounding effect; however this altered the behaviour of unconnected buildings leading to some undesirable responses. Xu et al. [8] showed that fluid dampers are quite effective in controlling the seismic response of connected buildings. Zhang and Xu [9,10] examined the effectiveness of fluid dampers in a coupled building control scheme and observed significant response reduction. The authors employed Maxwell model for fluid dampers, interconnecting two adjacent buildings, and noted reduction in response and increase in modal damping ratio. Zhu and Iemura [11] conducted an analytical study of connecting two parallel structures with passive devices and noted the effectiveness of coupling two adjacent structures for response control. The study of interaction between primary structure and an auxiliary structure was carried out by Zhu et al. [12], with an objective to reduce the seismic response of primary structure, and substantial reduction in response was observed. Ni et al. [13] found that hysteretic dampers are quite effective to control the seismic response of connected buildings. Matsagar and Jangid [14,15] studied the effectiveness of a coupled control scheme, involving base isolation and interconnecting viscoelastic dampers, and underlined that large isolation displacement of dynamically dissimilar buildings can be controlled by connecting them using viscoelastic dampers. Kim et al. [16] found that certain size of viscoelastic dampers in a coupled system reduces the seismic response. Interconnecting two adjacent buildings using friction dampers helps in reducing the response; the location of dampers is decided for optimal performance, observed Bhaskararao and Jangid [17]. Bharti et al. [18] proposed a coupled building control scheme interconnecting inline floors of two closely spaced adjacent buildings with semiactive Magnetorheological (MR) dampers, and noted that the control scheme is quite effective in response mitigation of both the buildings under wide range of ground motions.

Researchers have been exploring various approaches of seismic hazard mitigation of closely spaced adjacent buildings, by way of employing various control devices. Amongst various control devices, seismic base isolation has proved to be a time tested method and semiactive MR dampers have also emerged a very attractive proposition as control device. The current study aims to combine both the devices, thereby proposing a new coupled control scheme, which is called Hybrid control. Moreover, the results of the study may be useful, if a new building comes up adjacent to an already existing base isolated building.

The study investigates the comparative performance of three schemes of coupled building control, namely, *Semiactive*: adjacent buildings are connected at the floor levels through inline MR dampers, *Hybrid 1*: besides inline MR dampers, Building 1 is isolated at the base level with Laminated Rubber Bearing (LRB) and *Hybrid 2*: besides inline MR dampers, Building 1 is isolated at the base level with Lead Rubber Bearing. Further, influence of device parameters, that is, isolation parameters – damping, period, yield strength, and damper parameters – command voltage and damper location, has been investigated through parametric study. The results of numerical study show that Hybrid controls are performing more effectively in controlling the responses as compared to Semiactive control.

2. Structural modelling

Schematic representation of structural model of Semiactive control and Hybrid control has been shown in Figs. 1a and

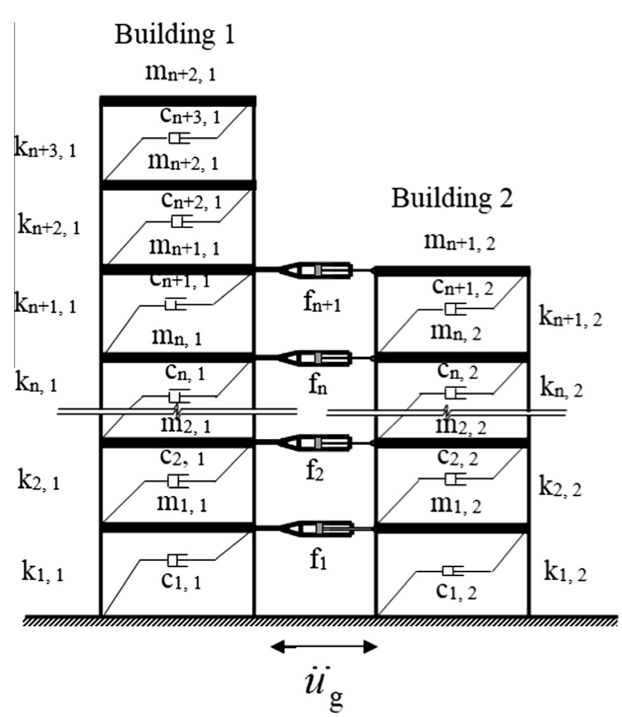

Figure 1a Coupled building model with fixed base.