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Experimental studies on nonlinear seismic control of a steel–concrete hybrid structure using MR dampers

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ABSTRACT

This article presents experimental studies on the feasibility of nonlinear seismic control of a 3-story steel–concrete hybrid structure using magnetorheological (MR) dampers. The control strategies included passive-on control, passive-off control and semi-active control, and strains gathered at the bottom of the steel columns were used as feedbacks to build the semi-active controller. For each control type, the control efficacy on structural response and damage was verified for the El Centro, Taft and Tianjin earthquake with specified peak ground acceleration (PGA) of 0.2*g*, 0.4*g*, 0.9*g* and 1.2*g* respectively. The test results show that (1) it is feasible to control the seismic response of the steel–concrete hybrid structure using MR dampers; (2) structure with semi-active control and passive-on control perform better in the shaking table test considering the maximum inter-story drift, displacement time history and energy dissipation capacity, compared to uncontrolled structure and structure with passive-off control; (3) there is also more structural damage in the passive-off and uncontrolled cases, proving the effectiveness of MR dampers in damage control. In addition, an inverse calculation method for strain is proposed to effectively utilize the strains measured during the shaking table test to obtain the stress and material damage process at measured positions, using damage model of the steel and concrete material.

1. Introduction

Steel–concrete hybrid structures have many advantages, such as the light weight, small cross-section, high stiffness and speedy construction compared to reinforced concrete structures, and good fire resistance, reduction in steel consumption and higher resident comfort level under wind loading compared to steel structures. However, due to their poor performance in the 1964 Great Alaskan Earthquake and the 1995 Kobe Earthquake, no more buildings using steel–concrete hybrid structural system were built afterwards. In recent years, a large number of super high-rise buildings using steel–concrete hybrid structural system were constructed in China, and extensive experimental studies have been conducted in order to explore the seismic performance of this type of structure, with some positive results.

New approaches are needed to enhance the seismic and collapse resistance of steel–concrete hybrid structures, while structural control techniques [1–3] have been proven effective, especially the semi-active control method [4] using MR dampers. For example, Dyke et al. [5] proposed a new clipped-optimal control strategy based on acceleration feedbacks and the control efficacy was verified by the shaking table test of a three-story model building. Ni et al. [6] proposed a neuro-control method for semi-active vibration control of stay cables using MR dampers. Lim et al. [7] conducted a shaking table test of a full-scale one-story building structure equipped with MR dampers, and found that MR dampers could mitigate the structural response under strong earthquake excitations effectively.

In addition, this type of dampers was also proven to have low power consumption, direct feedback, high reliability and fail-safe mechanism. The manufacturing issues, powering, range of variability of the mechanical parameters, dependence on the feed current and overall response time were studied by Occhiuzzi et al. [8], who found that MR dampers are quite versatile for the control of structural dynamic responses, and can be driven to operate in a rather broad range of physical behaviors. Sun et al. [9] conducted a shaking table test of a scaled three-story steel frame structure and the results showed that MR dampers slightly increased the structural stiffness and damping ratio. Yoshida et al. [10,11] conducted theoretical and experimental studies to examine the coupled lateral and torsional motions of building structures with asymmetric stiffness distribution. Shook et al. [12] optimized the fuzzy logic controllers by a genetic algorithm, and the controllers were designed to manage two 20 kN MR dampers for mitigation of seismic loads on a three-story steel frame benchmark building. The results

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