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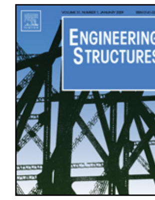

Experimental evaluation of the seismic performance of steel MRFs with compressed elastomer dampers using large-scale real-time hybrid simulation

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ABSTRACT

Real-time hybrid simulation combines experimental testing and numerical simulation, and thus is a viable experimental technique for evaluating the effectiveness of supplemental damping devices for seismic hazard mitigation. This paper presents an experimental program based on the use of the real-time hybrid simulation method to verify the performance-based seismic design of a two story, four-bay steel moment resisting frame (MRF) equipped with compressed elastomer dampers. The laboratory specimens, referred to as experimental substructures, are two individual compressed elastomer dampers with the remainder of the building modeled as an analytical substructure. The proposed experimental technique enables an ensemble of ground motions to be applied to the building, resulting in various levels of damage, without the need to repair the experimental substructures, since the damage will be within the analytical substructure. Statistical experimental response results incorporating the ground motion variability show that a steel MRF with compressed elastomer dampers can be designed to perform better than conventional steel special moment resisting frames (SMRFs), even when the MRF with dampers is significantly lighter in weight than the conventional MRF.

1. Introduction

Passive damping systems can significantly enhance the seismic performance of buildings by reducing drift and inelastic deformation demands on the primary lateral load resisting system, in addition to reducing the velocity and acceleration demands on non-structural components [1]. Among the different kinds of passive damping systems, solid viscoelastic dampers have been extensively studied. These dampers generally consist of solid elastomeric pads bonded to steel plates. The elastomer pads exhibit both viscosity and elasticity and their mechanical properties depend on loading frequency, deformation amplitude and temperature.

Many researchers have performed individual viscoelastic damper tests and developed models to predict damper behavior under earthquake loading. Tsai and Lee [2] and Kasai et al. [3] studied the effect of loading rate and temperature on viscoelastic materials and proposed fractional derivative models to predict damper behavior. Lee [4] studied the behavior of elastomeric dampers made of ultra high damping rubber and found from characterization tests the behavior of these dampers to be less sensitive to frequency and ambient temperature compared to conventional viscoelastic dampers. Sause et al. [5] developed a sequential asymptote formulation to model the cyclic behavior of ultra high damping rubber dampers.

Other studies have developed seismic design procedures for buildings incorporating viscoelastic dampers and used nonlinear dynamic history analysis to evaluate seismic performance and damper designs. Fu and Kasai [6] presented a simplified theory to design viscoelastic dampers for a given MRF. Their simplified design method has been verified by performing nonlinear dynamic history analysis for a ten-story steel MRF with dampers. Lee et al. [7] presented a simplified design procedure for buildings with viscoelastic or high-damping elastomeric dampers. The design procedure has been used recently to study the effect of the variation in steel moment resisting frame (MRF) properties and damper design criteria on the design of steel MRFs with elastomeric dampers [8]. The 2000 NEHRP Provisions [9] include equivalent lateral force and modal analysis procedures for buildings with damping systems including viscoelastic dampers. The validity of the 2000 NEHRP procedures has been assessed by Ramirez et al. [10].

Several experimental studies have been performed on steel frames with viscoelastic dampers. These studies include mainly shaking table tests similar to those conducted by Chang and

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