Seismic Response of Adjacent Structures Connected with Semi-Active Variable Friction Dampers

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In this paper, the responses of two adjacent structures connected with semi–active variable friction dampers (SAVFD) under various earthquake excitations are investigated. By controlling the clamping force, SAVFD is able to adjust its slip force and remain in slip state during an earthquake of arbitrary intensity. The objective of this study is to evaluate the optimum value of the gain multiplier and its importance in the structural–response reduction of coupled structures. The optimum gain multiplier, defined as the ratio of damper force to critical damper control force, is investigated for the SAVFD connected, adjacent structures subjected to four different types of earthquake ground motions. A numerical study is carried out for two adjacent, multi–degree–of–freedoms (MDOF) structures connected with SAVFD. The investigation is also carried out to determine the effectiveness of dampers in terms of the reduction of structural responses–namely, displacement, acceleration, and shear forces of adjacent, connected structures. In addition, to minimize the cost of the dampers, the study is conducted with only 50 percent of total dampers at optimal locations, rather than placing the dampers at all floor levels. The predictive control with direct–output feedback concept is considered, and the results are compared with uncontrolled and passive–control cases. Results show that by using SAVFD to connect the adjacent structures of different fundamental frequencies, earthquake-induced responses of either structure can be effectively reduced. Further, it is observed that two adjacent MDOF structures connected with 50 percent of the total dampers at proper locations reduces earthquake–induced responses as much as when they are connected at all floor levels; thus, the cost of the dampers can be significantly reduced.

1. INTRODUCTION

Many natural disturbances like strong earthquakes have caused severe damage to large–scale infrastructures. To protect civil engineering structures from such natural disturbances, structural–control devices have been developed in civil engineering structures to dissipate energy from such natural disturbances and reduce vibrations in structures, thereby reducing human and material losses. Structural control deals with modifying the response of structures to undesirable excitations. In structural control, large forces are required in order to reduce the earthquake response and limit the amplitude of motion. Based on the energy consumption, the control system can be classified as passive, active or semi–active.[1] A semi–active system combines the features of active and passive systems. They utilize the response of a structure to develop control actions through the adjustment of damping or stiffness characteristics of the system.[2] A variety of semi–active devices have been considered for seismic applications, including variable orifice dampers; variable friction devices; adjustable, tuned liquid dampers; controllable fluid dampers and variable stiffness dampers.[1] Because of their relatively high performance and low energy requirement, a numbers of different devices have been proposed for the practical implementation of semi–active control systems, and more research has focused on improving semi–active control devices or control laws to enhance its performance.[3]

A friction damper is a displacement–dependent energy dissipation device, and the damper force is independent of the velocity and the frequency–content of excitation. A friction damper consists of a frictional sliding interface and a clamping mechanism that produces a normal contact force on the interface. For a passive friction damper, the slip force of the damper is a pre–determined fixed value. A friction damper starts to slip and dissipate energy once the seismically induced damper force exceeds the pre–determined slip load, otherwise an inactivated damper behaves as a regular bracing system. The energy dissipated by the friction damper is proportional to the damper slip force. If the level of slip force is set too low, then the friction damper may not be efficient. If the slip force is set too high, during most of the earthquake the duration damper will not slip, hence no energy dissipation will take place and the damper will act as a regular bracing. During an earthquake, the damper may switch between slip and stick states, which can result in high–frequency structural responses. The structural responses of two adjacent buildings connected with friction dampers under various earthquake excitations has been investigated.[4] The researchers found that using friction dampers at an appropriate location and with appropriate slip force to connect the adjacent buildings of different fundamental frequencies can effectively reduce earthquake–induced responses of both buildings.

A semi–active damper is able to adjust its slip force by controlling its clamping force in real–time in response to a structure's motion during an earthquake. In order to determine the appropriate level of adjustable clamping force of the damper, semi–active friction dampers require a feedback–control algorithm and an on–line measurement of the structural response. The control action is carried out by adjusting the clamping force of the semi–active damper. It requires little energy, and it is not adding energy to the controlled structures, so a stability problem will not arise. However, the performance of the semi–active friction damper significantly depends on the control algorithm used. There are many control algorithms: