Chapter 10
Effective Configurations of Active Controlled Devices for Improving Structural Seismic Response

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ABSTRACT

Improving structural seismic response using dampers became a widely used method in the recent decades. Various devices were developed for seismic protection of structures and appropriate methods were proposed for effective design of control systems. An actual problem is how many dampers should be used as is their optimal location for yielding the desired structural response with minimum cost. A method for finding effective dampers’ placement and using amplifiers for dampers connection was recently proposed in the literature. The current study presents analyses of the amplification and placement of active controlled devices on the efficiency of a control system. A model of a twenty-story structure with active control systems including different dampers configurations is simulated. The response of the structure to natural earthquake excitations is also reported. The results of this study show a method of selecting proper configuration of active devices allowing cost effective control.

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INTRODUCTION

Reduction of structural responses to earthquakes is a subject that is widely investigated during the last decades. Structural control is known as one of the effective ways for enhancing structural seismic response. Various structural control strategies are developed and implemented in practice. Structural control applications are effectively used in new buildings and also to retrofit existing structures all over the world.

For example, steel moment frames with fluid viscous dampers located at the ground floor are used for seismic retrofitting of a 4-story reinforced concrete building of the Woodland Hotel located in Woodland, California. Seismic rehabilitation of the ten-story MUCTC building in Montreal was achieved by Pall friction dampers in steel bracing. Navy Building in San Diego is equipped with viscoelastic dampers. A tuned mass damper is used in City Corporation Building in NY City. An active mass damper is installed in the Nanjing television tower in China.

For implementation of structural control algorithms passive, semi-active and active devices are used. Passive devices use the energy of structural motion to dissipate energy. This group of devices includes viscous dampers, viscoelastic dampers, friction dampers, tuned mass dampers, base isolation devices, etc. (Soong, 1997). They require no external energy, but the properties of these devices are constant and the forces across these devices are not changed according to any optimal control law.

Modern approaches are developed to improve the efficiency of passive dampers. Seismic design of friction dampers based on the desired structural performance yields effective passive energy dissipation (Tabeshpour, 2010). A gradient-based evolutionary optimization methodology is presented for finding the optimal design of viscoelastic dampers and their supporting members (Fujita, 2010). Finding optimal location and characteristics of triangular adding damping and stiffness dampers in moment resisting steel structures is an additional topic that is investigated (Yousefzadeh, 2011).

Active devices are able to change the control force, applied to the structure according to the optimal control requirements. They allow more effective control, but external energy source is required for activation of these devices. In other words, active controlled devices externally activated and apply control forces to the structure in order to improve its performance. Active devices include active tendons, active tuned mass dampers and actuators.

To reduce the energy, required for activation of the devices, semi-active dampers are used. In these devices a relatively small energy amount is enough to change the dampers properties so that the energy of structural motion would yield damping forces that are close to the optimal control force values. Semi-active devices include active variable stiffness systems, electro-rheological dampers, magneto-rheological dampers, semi-active variable friction dampers, shape memory alloys and piezoelectric materials etc. In order to ensure the structural safety, reliability and durability, pole assignment method, optimal control method and independent model-space control method are usually used. Modern control strategies are also developed for active and semi-active systems (Gu, 2008).

Hybrid applications of active and passive devices are also known. For example, magneto-rheological dampers are successfully used as a part of base isolation systems (Ribakov, 2002). Selective control is an effective algorithm for such systems (Ribakov, 2003). A hybrid isolation system, comprised of a bidirectional roller-pendulum system and augmented by controllable magnetorheological dampers is proposed to reduce the potential for damage to structures and sensitive equipment (Shook, 2007). Comparison of neural network control, LQR/clipped opti-
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