Chapter 35
Passive Control Techniques and Their Applications in Historic Structures

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ABSTRACT

Preservation of historic heritage is an endeavor of great significance. Environmental causes and earthquake activity have deteriorated and damaged monuments of important historical value. Passive control techniques that have been used for many years to control vibrations of structures and machines could also be used to protect historic structures from earthquakes. These passive techniques not only increase the seismic safety of structures but also respect their appearance which can be significantly altered by conventional strengthening techniques. This chapter reviews the most important passive techniques and presents selected applications to significant historical structures and monuments.

INTRODUCTION

Protection of structures from earthquakes is an important subject directly related to life safety. Historical structures or monuments have additional significance since they form a part of the cultural heritage of countries that need to be preserved for future generations.

Seismic resistance codes have been improved and new constructions are able to sustain strong earthquake excitations. Historical structures though need to be seismically upgraded most of the times to satisfy the new code's seismic demands and to avoid damage or destruction from strong future earthquakes.

Initially, the condition of the existing structure is evaluated and the available strengthening techniques are examined. Conventional structures resist the dynamic loads by a combination of strength, flexibility, and deformability. During strong motions structures absorb a portion of the energy that can lead to damage and ultimately destruction. Common strengthening techniques (ElGawady et al., 2004) usually disrupt architectural features which is an important concern for historical structures.

Alternative approaches have been developed that incorporate seismic protection systems in the structures such as passive, active, semi-active and hybrid control systems. Passive control systems

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use simple, low cost devices that reduce the vibration of structures by absorbing and dissipating energy. The controller starts to operate and produce control forces with the motion of the structure. The efficiency of the passive control systems depends on the adjustment of the system's parameters to respond appropriately to expected input motions and structural behavior. If there is a significant change in the excitation signal the efficiency of the passive control system may be reduced considerably since the control forces cannot be adjusted in real time. Passive control systems are inherently stable and they oppose the motion reducing the structure's vibrations without using external power. Their operation is based on the open loop scheme (Figure 1a).

Active control systems are more sophisticated and costly systems that can control the vibrations of a structure by supplying the control force adjusted in real-time according to the desired output. The force is applied by an externally activated device (control actuator) according to the computer that processes the information based on the measurements provided by the sensors. They operate based on a close-loop scheme (Figure 1b) since there is a feedback loop that helps to adjust the control force. They need external power source to operate (Datta, 2003; Soong et al., 1991).

Semi-active control systems require less control energy since they use the motion of the structure to produce the required control force. They do not add mechanical energy to the system but they have properties that can be controlled to reduce the response of the structure (Spencer and Nagarajaiah, 2003). Hybrid control systems require little power to operate since they combine passive devices and active controllers.

Passive control systems have been used more than the other structural control schemes to mitigate the response of structures under dynamic loads. Their simplicity, low cost and inherent stability overpass their disadvantage of not adapting the control force in real time. They have also been used to rehabilitate old structures that do not comply with the current seismic codes. Passive control systems include energy dissipation devices and seismic base isolation. In the next sections the basic characteristic of commonly used passive control systems are introduced. Some applications to historical structures are also presented.

PASSIVE CONTROL SYSTEMS

Energy Dissipation Devices

A vibrating structure would continue to move without stopping if there was not a mechanism to dissipate energy. This mechanism is called damping which is caused by the air resistance the structure encounters as it moves and by inherent properties of the structure (Nashif et al.,1985). Damping transforms the mechanical energy induced to the system to other types of energy with the largest part converted to heat. The inherent damping in the vibrating structures originates from material damping (loss of energy per deformation cycle) and friction at the connections. The level of the

Figure 1. (a) Open loop block diagram; (b) closed loop block diagram