Abstract

The current trend towards structures of increasing heights and the use of high strength materials and advanced construction techniques has led to more flexible and light structures, with little capability of energy dissipation. Understandably these structures are very sensitive to external excitations such as winds, ocean waves and earthquakes, resulting to vibrations that induce possible structural failure in serviceability or strength issues. Therefore, the adoption of outside energy dissipation mechanisms, particularly in high-rise structures, for suppression of their vibrations, has gained much focus the last decades.

The most commonly used such device is the Tuned Mass Damper (TMD), which is based on the inertial secondary system principle and consists of a mass attached to the structure through a spring and a dashpot. The Tuned Liquid Column Damper (TLCD) relies on the same principle; the dead mass is replaced by a liquid mass, which can be used for other purposes during situations that do not require the use of it as an external damping mechanism. It consists of a U-shaped tube, with the same section diameter in the horizontal and vertical parts of it, filled with liquid, preferably water. At the center of the horizontal section of the tube an orifice plate exists that causes energy dissipation in the vibration of the liquid. The motion of the liquid inside the tube counteracts with the structure producing the desired energy dissipation. As an improvement of this system a new damping mechanism has been recently developed, the Liquid Column Vibration Absorber (LCVA), with different section diameters in the two parts of the tube containing the liquid. The LCVA provides better architectural results and higher ability of energy dissipation.

The present thesis constitutes a succession of a previous research I did during my undergraduate studies. That thesis focused on the basic principles of use of the TLCD as an energy damping mechanism for different types of external excitation (wind, ocean waves, earthquake) and the way in which the parameters of geometry of the TLCD influence the response of the main system. In the current thesis the study is expanded to include not only the Tuned Liquid Column Damper but also the relevant Liquid Column Vibration Absorber, whereas the response is computed in the frequency domain that provides a more in depth understanding. Besides the passive design, the implementation of active and semi-active control techniques are considered. Also, a comparison of the liquid column dampers (TLCD and LCVA) to the Tuned Mass Damper is incorporated, in order to compare the main types of dampers whose principle of work relies on the movement of an auxiliary mass. Moreover, the issue of multiple dampers is studied. The thesis, regarding all the above-mentioned topics, focuses on earthquake excitation

and the investigation of the implementation possibilities of mass dampers in the field of aseismic design either as passive or as semi-active and active mechanisms. The advantages that column dampers present in suppression of structure seismic vibrations are discussed, considering also the relevant problems that are raised. Along with the theoretical approach, an experimental investigation of the function of Tuned Liquid Column Dampers is conducted in the earthquake laboratory of Aristotle University of Thessaloniki. This investigation is focused on semi-active use of them as damping mechanisms.

Through the present thesis, a design procedure of the parameters of each damper is attempted, aiming at the optimal response of the main structure subjected to earthquake excitation. The criteria considered are maximum displacement (involving strength) or acceleration (involving serviceability and occupant discomfort) standards. For this purpose the definition of the optimal coefficient of head loss for the orifice is especially considered, since this issue combines with serious problems –dependency on the amplitude of the excitation- that have not been efficiently addressed by previous investigations.