Tuned Liquid Column Dampers with Period Adjustment Equipment for Earthquake Vibrations of High-rise Structures

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Abstract

This paper investigates the application of a bi-directional vibration system, namely Tuned Liquid Column Damper with Period Adjustment equipment (TLCD-PA), which is used to decrease the vibrations of high-rise buildings due to earthquake oscillations. The TLCD-PA is a two degree-of-freedom (2DOF) system consists of two U-shaped tubes filled with water (2TLCDs) and a pendulum. The second TLCD, namely Period Adjustment equipment (PA), is smaller than the first one and placed above it. The two TLCDs are connected through the air tubes at the top of vertical columns. The liquid displacement in the PA system moves the plate at the middle radially, which is connected to the pendulum. The liquid columns, the air tubes and the pendulum provide spring stiffness for the system. On the other hand, the liquid movement in the two TLCDs provides nonlinear damping for the equipment. The liquid mass in the two TLCDs and the pendulum provide the required mass for the system. Therefore, this type of damper consists of many adjustable parameters that help for the better tuning of frequency and damping coefficients.

In this paper, the effect of various important parameters of the TLCD-PA on the earthquake vibrations of tall buildings is investigated. The structure is modeled as a single DOF system equipped with TLCD-PA at the top of the building. Kobe earthquake data is employed for the modeling of earthquake oscillations, and the nonlinear Newmark method is applied for the displacement, velocity and acceleration calculations. The effects of area ratios and length ratios for the U-shaped tubes of two TLCDs are investigated. Moreover, the effects of pendulum parameters such as mass, spring stiffness and length of the pendulum are discussed. The frequency effects of TLCD and PA equipment are also studied. It is shown that the TLCD-PA is a useful system for the reduction of building vibrations. It is also shown that how the various parameters assist the designers to the better adjustment of the TLCD-PA system. This study helps the researchers to the better understanding of the TLCD-PA system, and leads the designers to achieve more efficient dampers for the high-rise buildings.

Keywords: Tuned Liquid Column Damper, Period Adjustment Equipment, High-rise Structure, Earthquake Vibration.

1. INTRODUCTION

In recent years, the construction of new high-rise buildings are facilitated and developed in many countries due to the lighter and stronger materials. These tall and slender buildings are usually subjected to wind and earthquake vibrations, which may cause structural failure, discomfort to occupants and malfunction of equipment. Therefore, mitigation of wind and earthquake induced vibrations by using supplemental damping devices has been widely investigated.

Among passive control devices, tuned mass dampers (TMDs) and tuned liquid dampers (TLDs) have been widely employed for decreasing the wind and earthquake induced vibration of tall building structures. The original idea of tuned liquid column damper (TLCD) was developed by Sakai et al. [1] for suppression of horizontal motion of structures. After that, quite a few research papers, namely Xu et al. [2], Hitchcock et al. [3], Balendra et al. [4], Min et al. [5] and Felix et al. [6], have verified its effectiveness for suppressing wind induced horizontal responses, among whom Hitchcock et al. [3] even investigated a general type of TLCDs that have non uniform cross-sections in the horizontal and vertical columns, termed as liquid column vibration absorber (LCVA). Recently, the application of TLCDs was further extended to the suppression of pitching motion for bridge decks (e.g., Xue et al. [7] and Wu et al. [8]). For the application to the control of horizontal motion toward implementation, some researchers have spent efforts on determining optimal TLCD designs, such as Chang et al. [9] and Chang [10] on undamped structures, Wu et al. [11,12] on damped structures, and Yalla et al. [13] on both damped and undamped structures. Their results of optimal parameters is provided for the case that loading on buildings is white-noise type, such as wide-banded along wind loads.

There are also some applications of TLCD technologies, including period adjustment mechanisms. By providing a Tuned Liquid Column Damper with Period Adjustment Equipment (TLCD-PA), the behavior of