The 2016 World Congress on
The 2016 Structures Congress (Structures16)
Jeju Island, Korea, August 28-September 1, 2016

Statistical analyses for the response of coupled building-controller systems subjected to dynamic loads

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ABSTRACT

The following paper presents a case study of the statistical time series and frequency contents for a controlled structural model of a steel frame building. The control systems include three passive vibration control devices: tuned mass damper (TMD), tuned liquid damper (TLD) and tuned liquid column damper (TLCD). From experimental results it could be concluded that the TMD control system is a more sensitive controller than TLD and TLCD systems in terms of vibration mitigation.

1. INTRODUCTION

Passive control systems are being progressively used in the vibration control of structures subjected to dynamic loads (Adeli and Kim,2006).The most commonly used passive control system could be listed as tuned mass damper (TMD), tuned liquid damper (TLD) and tuned liquid column damper (TLCD), and so on. Tuned liquid column damper, proposed by Sakai et al. (1991) combines the liquid mass and orifice damping effect to minimize the vibration. Using the similar concept TLD also works fine. The main advantages of using TLCD and TLD are that they can be used as both controller and reservoir for the daily water supply. A big disadvantage for these systems is when the devices are in empty conditions and the lateral loading is being applied to the system. Moreover, it is much more difficult to tune the water level to control the vibration effectively. TMD is a reliable solution in such situations. An auxiliary mass attached to the top of the structure by a spring and a dash-pot. TMD system became quite popular worldwide since 1971. Crystal Tower Building in Osaka, the Citicorp Center in New York City, Taipei 101 in Taiwan and Sydney tower in Sydney are the successful examples of

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Note: Paper to be submitted to "Computers and Concrete, An International Journal" for the purpose of Special Issue.

TMD application. Many papers have been published on the performance investigation of these controlling systems (Kasai et el. 2008; Bigdeli and Kim, 2016).This study presents the statistical analysis of the experimental study for a three story building attached with TMD, TLD and TLCD control systems to assess the performance of the structure.

2. RESPONSE THEORETICAL BACKGROUND

The mechanical configuration of a controller used as a vibration absorber could be simplified as combinations of a spring and a mass attached on the top of a multi-story structure. In this case, dominant general equation of motion for the coupled structure and the absorber for a three dimensional (3D) structure is as following (Bigdeli and Kim, 2016):

$$M\ddot{x} + C\dot{x} + Kx = -Mr_g\ddot{x}_g \tag{1}$$

where, *M, C* and *K*, denote mass, damping and stiffness matrices of the structure, respectively. The $\ddot{x}, \dot{x}, x$ represents the acceleration, velocity and displacement response of the structure, respectively. The excitation dynamic signal has been indicated by x and r_g are defined as the displacement and the ground influence vectors.

3. EXPERIMENTAL STUDY

A scaled structural model of a 3D 3-story moment-resisting steel frame building structure is selected to perform the experiments. The total height of the building is 930 mm, and the natural frequency of the system is 2.7 Hz. The diameter for the section area of each steel column is 5 mm and the story height is equal to 310 mm for all three stories. All degrees of freedoms (DOFs) are restricted at the base level. Each floor configuration includes: a rigid steel square plate with dimensions of 300 * 300 mm and with weight of 3436 gr where it contains three degrees of freedom for translation in x-, y-directions as well as a rotation around a vertical line passing through centers of mass at each floor. Therefore, the total number of DOFs after application of the boundary conditions (i.e., rigid diaphragm, Guyan reduction of vertical DOFs, and rotational DOFs around x- and y- axes) is equal to 9. However, it was equal to 42 prior to application of all boundary conditions. The employed model is described in details in the papers published by Bigdeli and Kim (2015) and (2016).

Three passive vibration control devices including: TMD, TLD and TLCD were being used in this study. The type of material used for the fabrication of TLCD and TLD devices is a light fiberglass, while the steel material was used in TMD fabrication. The total weight of each device is less than 3% of the entire steel structure and this value kept constant during the execution of the experiments for all three systems. The water inside the containers is in a direct contact with the atmosphere and it also can freely move inside the container. In order to compare the results properly a few points are considered. Firstly, all three devices have the same primary mass, which means that TLCD and TLD and TMD are similar in weight. Secondly, the same amounts of solid or water mass are added to the system including water mass to TLCD and TLD and solid mass to TMD at each step of the experimental test. Lastly, the dimensions of the devices are designed in a way to be identical in order to ensure the minimum effects on