Passive control for far-field earthquake oscillations of tall buildings including soil structure interaction

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Abstract

This paper investigates the effects of passive control system for earthquake oscillations of tall buildings including soil structure interaction (SSI) effects. Tuned Mass Dampers (TMDs) are utilized as passive controllers for the system. The system is modeled as a 40-story building with 160m height considering the translation and rotation of foundation. The SSI effects are considered for the 3 soil types, i.e. the soft, medium and dense soils; and their results are compared with the fixed foundation results. The Newmark method is utilized to achieve the displacement, acceleration, and drift of different stories. To illustrate the results, 8 far-field earthquake data are applied to the model. The Ant Colony Optimization (ACO) method is employed to obtain the best parameters for the TMD device. The design parameters are assumed as the mass, spring stiffness and damping quantity. The objective is to reduce the maximum drift of the structure. The results show that the TMDs are effective devices to reduce the oscillations of tall buildings including SSI effects. In addition, it is indicated that the ACO method can be effectively applied to design the optimum TMD devices. The effects of optimized TMD parameters on the drift, displacement and acceleration of the building are also investigated in this research.

Keywords: Tall Building, Earthquake Oscillations, Tuned Mass Damper, Soil Structure Interaction, Ant Colony Optimization.

1. INTRODUCTION

In recent years, high-rise buildings are widely developed and employed in most countries. They are usually subjected to the earthquake vibrations. Therefore, the study of tall buildings vibration mitigation and various absorbers has attracted the interest of many researchers. Moreover, the soil characteristics and the interaction between soil and structure greatly influence the structural responses. The tuned mass damper (TMD) is one of the simplest and the most reliable control devices among the numerous passive control methods. It can dissipate energy through the interaction of inertial force produced by mass movement and damping effects induced by damper. As Ormondroyd and Den Hartog [1] mentioned, the application of TMD was firstly proposed in 1909. Since then, many theoretical and experimental researches have been performed to study the TMDs mechanism of vibration mitigation and their application for the structures. The TMDs are usually installed on the top floor, and several researches have been conducted to study their effectiveness for earthquake [2] and wind [3,4] excitations. Gupta et al. [5] investigated the effects of several TMDs with elastic-plastic properties on the response of single degree of freedom structures subjected to Kern County earthquake (1952). To investigate the effect of TMDs on the fundamental mode response, Kaynia et al. [6] studied the optimum reduction of structures response subjected to 48 earthquake spectra. They figured out that the TMDs are less effective in decreasing the response of structures than previously thought. Sladek and Klingner [7] investigated best parameters of a TMD placed on top floor of a 25 story building, based on the minimization of response to sinusoidal loading. An optimization method is employed by Wirsching and Campbell [8] to calculate the TMD parameters for 1-, 5- and 10-storey buildings. According to their study, TMDs are effective devices in reducing response. Several studies on the application of TMD and its best values are performed by other researchers such as Villaverde et al. [9]. Later, Sadek et al. [10] presented some formulations for computing the optimal parameters of TMD device based on the equal damping of the first two modes of system. Considering soil effects, the structure response differs from the fixed base model. The oscillation energy is actually transferred to the soil through the foundation. Therefore, the soil and structure influence each other, which is called the soil-structure interaction (SSI). Various investigations are