Bee Colony Optimization of Tuned Mass Dampers for Earthquake Vibrations of High-rise Buildings Including Soil Structure Interaction

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Abstract

This paper investigates the optimization of Tuned Mass Dampers (TMDs) for high-rise buildings. The model is assumed as a 40 story building with 160m height considering the translation and rotation of foundation. The Soil Structure Interaction (SSI) is considered for the better prediction of building's response. To illustrate the results, Bam earthquake data is applied to the model. The three soil types, i.e. soft, medium and dense soil are utilized, and the results are compared with the fixed based model. The model is based on time domain analysis, and Newmark method is used to obtain the displacement, velocity and acceleration of different elements. The Artificial Bee Colony (ABC), a heuristic method based on the behavior of bees forage for food, is employed to obtain the best parameters for TMD device. The design variables are assumed as mass, damping and spring stiffness quantity. The objective is to decrease both the maximum displacement and acceleration of the building.

The results show that the presented model can be effectively applied to evaluate the response of high-rise buildings including SSI effects. It is indicated that the results obtained by this model is more accurate than the results of fixed based model. The effects of TMD on the oscillations of structures including different soil characteristics are also investigated. It is shown that the TMD is more effective for soft soil foundations. It is also shown that how the bee colony optimization technique can be employed to design the optimum TMD for the minimum displacement and acceleration. This study leads the researchers to the better understanding of earthquake oscillations of the high-rise buildings, and helps the designers to achieve the optimized TMD for the structures.

Keywords: High-rise Building, Earthquake Vibration, Tuned Mass Damper, Soil Structure Interaction, Artificial Bee Colony optimization.

1. INTRODUCTION

In the last decades, high-rise buildings are widely developed and employed in most countries. These structures are generally flexible and possess low damping properties. 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.

A tuned mass damper (TMD) is a kind of vibration absorber consisting mass, spring and viscous damper attached to the vibrating system to mitigate oscillations. It passively dissipates 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 storey building, based on 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. Ohno et al. [9] presented the optimized TMD parameters based on the minimization of