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Ambient Vibration Tests and Finite Element Analysis for Dynamic Properties of Brick Masonry Inverted Bell-Shaped Chedi

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Abstract

This research is aimed to study fundamental dynamic properties of an esteemed brick masonry inverted bell-shaped chedi at Phrathat Doi Suthep temple, Chiangmai, Thailand, by using full-scale ambient vibration tests associated with the finite element analysis. The study results showed that the finite element analysis indicated 3.817 Hz , 3.836 Hz and 9.294 Hz for the natural frequencies of the first modes on the x, y and torsion directions. From the ambient vibration measurements, the frequencies were 4.086 Hz, 4.025 Hz and 10.819 Hz. In comparison, the finite element gives the similar frequency values with the measured ones. The discrepancies are respectively 6.59, 4.70 and 14.09 percent. Hence, the validation of the finite element model has been made and used for vibration analysis presented in the accompanied paper (Seismic Performances of Brick Masonry Inverted Bell-Shaped Chedi)

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1. Introduction

There are a large number of buildings in Thailand with historical significance being named the World Heritage Site. Most of the structures have been publically recognized as symbols standing as sacred reminders

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of the Buddha and the Dharma. They are also the important references for historical education in the region. It is therefore necessary to preserve these buildings for future generations.

Pagoda or Chedi, a term describing a Buddhist stupa, is one of such a kind of the historical buildings having solid inverted bell shaped geometry with no interior space in typical [1]. The geometrical dimension utilizes his self-weight enabling the brittle brick masonry material to be efficiently adopted with compressive-arch transferring mechanism under gravity loading. The buildings have been long lasted for a hundred of years with exceptional partially damaged under past potential earthquakes.

In this paper, Chedi at Phrathat Doi Suthep temple was selected as a case study. The Chedi is one of the top sacred sites to Thai people located on Suthep Mountain, Chiangmai city, Thailand. Fig. 1 shows the impressive view of the Chedi and his geometrical dimension. First, dynamic properties e.g. natural frequencies and mode shapes were investigated through ambient vibration observation. Then, finite element analysis was employed to obtain the dynamic responses in higher modes. The two results were compared to verify the finite element model and then applicable for further analyses [2].

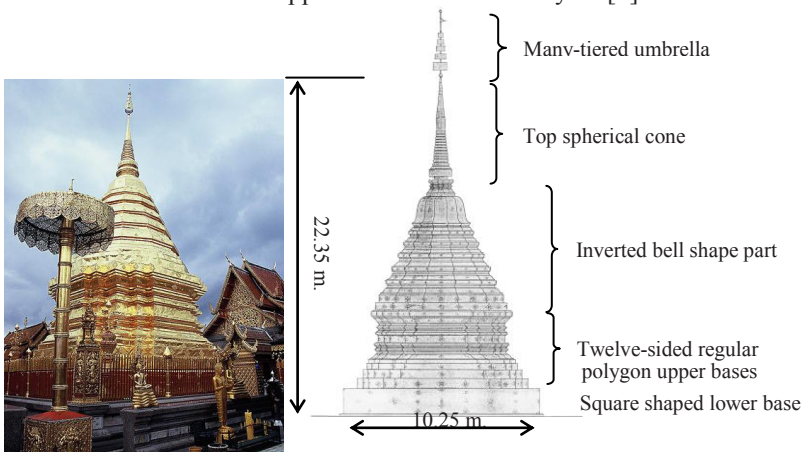

Fig. 1. Chedi Phrathat Doi Suthep

2. Ambient vibration observation and finite element model

2.1. Apparatus

The ambient vibration test for natural frequencies and mode shapes has been a subject of interest for describing the linear behavior of structures used in structural monitoring and control studies [3]-[6]. In this measurement, it was performed using velocity sensors. The apparatus was composed of (1) 3 velocity transducers with 3 directional measurements in x, y and z for each sensor (2) Cables connecting the sensors and recorder (3) Portable computer for controlling sampling rate, digital converter and duration of recording and (4) Batteries. The apparatus could detect the movements with frequency in the range of 0.1 to20 Hz and the highest velocity of 2.5 cm/s.

2.2. Measurement on ambient vibration responses

As seen in Fig. 2, for measuring the ambient vibration responses, velocity of the motions were detected using velocity transducers attached at the top part (point A). To obtain the translational vibration mode shape, another velocity transducer was placed at lower positions in z direction (vertical), e.g. B, D, E, H, I, J, K, from