Human-Induced Vibration Control with TMDs for Guangzhou Asian Games Comprehensive Museum

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Guangzhou Asian Games Comprehensive Museum is one of the permanent buildings for the 2010 Guangzhou Asian Games, whose bowl-shaped main body is a steel structure with the largest cantilever length of more than 30 meters. The structure has a low natural frequency, so it tends to be excited by people synchronizing walking with amplification of resonance, which will affect the serviceability. A large amount of analysis and field-tests are performed for this historical museum with tuned mass dampers (TMDs) being used to reduce human walking induced vibration. The results showed that TMDs can control the structure vertical vibration effectively, with the efficiency of over 50%. The research results have obvious significance for similar projects.

1. INTRODUCTION

Long-span structures and high-rise structures have a low natural frequency, so these constructions tend to be excited by people synchronizing walking with amplification of resonance, which will affect the serviceability and the safety of the structure. Human-induced vibration problems include three aspects: the walking excitation load, the evaluation criterion of serviceability and the vibration control. The dynamic loading caused by people synchronizing walking is complicated, which generates forces in three directions, the vertical, horizontal and longitudinal. The typical frequency ranges of people in various activities are revealed: walking at 1.6 to 2.4 Hz, running at 2.0 to 3.5 Hz, jumping at 1.8 to 3.4 Hz, and bouncing at 1.5 to 3.0 Hz, by statistics and distributions of stride frequency done by scholars from several countries.

The forces in three directions generated by people in different activities can be expressed in the form of Fourier series, and the harmonic components of at most the first five orders are usually considered in practical application. The forces in three directions generated by people in different activities can be expressed in the form of Fourier series, and the harmonic components of at most the first five orders are usually considered in practical application.1–4

In terms of the evaluation criterion of serviceability, the acceleration is usually used as the indicator for its convenience of being measured. The evaluation of human vibration serviceability is a complex problem, because different people react differently to the same vibration and the same person reacts differently to the same vibration under different conditions. Although quite a bit of research has been done by scholars from different countries, a consistent and definitive conclusion cannot be reached. The indicators used in standards of different countries are different.

The measures to control human-induced vibrations are various, in which installing dampers is a cost-effective way. Compared with simply increasing the stiffness of structures or varying the mass distribution, dampers are set without too many changes to the original structure. The common dampers used in vibration control are AMD (active mass damper) and TMD (tuned mass damper). TMD is widely used in vibration control of long-span structures for its economics and simplicity. TMD consists of masses, springs and damping systems, whose working principle is to adjust its vibration frequency to near the natural frequency of the main structure, and to change the structural resonance characteristics, in order to achieve the damping effect.

The bowl of Guangzhou Asian Games Comprehensive Museum is a steel structure with the largest cantilever length of more than 30 meters. The vertical vibration frequencies of the structure are very intensive and cover the frequency range of people normally walking, so the influx of a large number of people may cause serviceability problems. TMDs were used to reduce human-induced vibration for this historical museum.

2. THEORY

2.1. Building Aspects

The real shot of the Guangzhou Asian Games Comprehensive Museum is shown in Figure 1. The usable area during the Guangzhou Asian Games is 3677 m$^2$, the plan view size is 36 m × 35 m, and the roof height is 25.8 m. The museum consists of the exhibition room under the audience platform, spiral ramp exhibition room and the roof connector of two buildings. As shown in Figure 1, the bowl is a cantilever structure, with the largest cantilever length of 33 m. The bowl is supported on the core tube, whose plan view size is 8 m × 6.6 m.

Because of the long cantilever, the bowl of the structure has a low natural frequency, which is lower than 3 Hz. According to the Technical specifications of urban pedestrian overcrossing and underpass, the natural frequency of the structure should be controlled under 3 Hz, in order to keep away from the human walking frequency (1.6~2.4 Hz). Thus, measures