Long-term vibration serviceability of a steel-plated stress ribbon footbridge

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Summary

This paper describes the dynamic analysis and vibration serviceability assessment of an in-service steel-plated stress-ribbon footbridge sited in Valladolid (Spain). Because of its slenderness and singularity, this footbridge is a typical lightweight structure sensitive to dynamic excitation produced by pedestrians. A continuous vibration monitoring system which measures the acceleration and the environmental factors has been installed. The data collected have been used to identify the dynamics of the structure and assess its vibration serviceability under in-service pedestrian traffic. Firstly, peak-acceleration-based test for single-frequency excitations are undertaken. Secondly, standards ISO 2631 and ISO 10137, suitable for general human exposure evaluation to whole-body vibrations, are used to evaluate the long-term vibration serviceability since they take into account the duration of the vibration exposure as well as the frequency content of the excitation.

Keywords: Vibration serviceability; structural monitoring; footbridges; operational modal analysis; human-induced vibrations.

1. Introduction

The long-term vibration monitoring of civil engineering structures is increasingly used to monitor both the vibration serviceability and the structure integrity. A number of examples of bridges and footbridges equipped with a monitoring system can be found [1], [2]. The main problem for wide spreading the use of monitoring systems is the cost associated to the installation of the measuring system. Recently, a successful attempt of reducing cost of monitoring systems has been carried out by the authors through the use of low-cost MEMS accelerometers to measure structure vibration. Thus, a new low-cost continuous vibration monitoring system using MEMS-based accelerometers has been developed and installed on an as-built steel-plated stress-ribbon footbridge sited in Valladolid (Spain). Additionally, the wind and environmental temperature conditions are monitored [3]. This is a slender and lightweight structure born by a pre-tensioned catenary-shape steel band. The structure has only one span of 85 m that provides minimal visual impact on the surroundings [4]. Its dynamic behaviour is quite complicated showing lateral, torsional and vertical modes, low natural frequencies and low damping coefficients, which might lead to excessive human and wind-induced vibrations (compromising the vibration serviceability limit state).

Regarding vibration serviceability of footbridges, there is a clear lack of data from real-life footbridges subjected to in-service traffic. In this paper, the acceleration data collected from this system have been used to feature the long-term vibration serviceability of the structure under normal pedestrian traffic.

Current codes and design guidelines for footbridges consider single-axis, single-frequency excitation and rely on peak-acceleration-based criteria [5], [6]. However, in this work, standards ISO 2631-1:1997 and ISO 10136:2007, suitable for general human exposure evaluation to whole-body vibrations, are used to obtain valuable information about the vibration serviceability since

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