Comfort in Slender Bridges Subjected to Traffic Loading and Hammering Effects

Alfredo CAMARA
PhD, Civil Engineer
Imperial College London
London, UK
a.camara@imperial.ac.uk

Khanh NGUYEN
PhD, Civil Engineer
IETcc-CSIC
Madrid, Spain
khanh@ietcc.csic.es

Ana M RUIZ-TERAN
PhD, Civil Engineer
Imperial College London
London, UK
a.ruiz-teran@imperial.ac.uk

Peter J STAFFORD
PhD, Civil Engineer
Imperial College London
London, UK
p.stafford@imperial.ac.uk

Summary

The verification of the Serviceability Limit State (SLS) of vibrations due to traffic live loads is typically ignored in the design of road bridges with conventional concrete decks. However, the vibrations perceived by pedestrians usually govern the design in slender and light-weight modern structures that take advantage of the improvement in the structural efficiency, material performance and constructive procedures. On the other hand, the comfort of the vehicle users is traditionally ignored in the design of the bridge because pedestrians are usually more sensitive to vibrations. However, in many highway bridges without pathways the only users of the structure are those in the vehicles (drivers and passengers). Considering all the possible bridge users and their specific sensitiveness, this paper addresses the vibration serviceability in a slender under-deck cable-stayed bridge subjected to heavy traffic loading. In this structure the prestressed concrete deck spans a distance of 80 m with a depth-to-span ratio of 1/80. The vehicle-bridge interaction accounts for aspects traditionally ignored like the wheel dimensions and the cross-slope of the bridge. A large number of time-history analyses is conducted to address the influence of road and vehicle properties on the SLS of vibrations. This work is completed with the study of the vehicle impact when it enters and leaves the bridge. The results clearly demonstrate the influence of the wheel dimensions and the road conditions, as well as the importance of high-order modes on the response.

Keywords: Slender bridges; comfort criteria; pedestrians; vehicle users; wheel size; vehicle velocity; hammering effect.

1. Introduction

The verification of the Serviceability Limit State (SLS) of vibration has been traditionally ignored in the design of conventional bridges. However, traffic-induced vibration can be significant in slender structures. Vibrations are so relevant in the design of slender decks that usually limit its depth [1].

The simplest way of controlling the SLS of vibrations is by indirectly limiting the bridge static deflection under the live load [2]. Recently, it was shown that displacement-based methods can lead to unacceptably unsafe estimations of the vibrations perceived by the bridge users [3]. Two main reasons lay behind this relevant conclusion in slender bridges; (1) the response is not clearly dominated by the fundamental vibration mode; and (2) the pavement roughness is essential and it should be included through vehicle-bridge interaction models [4,5]. High-order modes have an important contribution in the overall response and time-history analyses of the accelerations recorded in three-dimensional (3D) Finite Element (FE) models are generally required in comfort studies.

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