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Comparison of Flutter Derivatives for Kao Pin Hsi Bridge and Flat Plate

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Abstract: Focus of this work is put on evaluation of dimensionless aeroelastic coefficients, i.e. flutter derivatives, which are considered to be indicators of the aeroelastic stability of bridges. A comprehensive experimental study on dynamic wind-induced behavior of the Kao-Pin-Hsi bridge in Taiwan is described. The results are compared to those of the thin flat plate with high width to height ratio, which previously proved to be aeroelastically stable.

Introduction

In the last few decades, significant development in building technology has been achieved, which allows for a major increase in span length of cable-stayed and suspension bridges. However, these structures characterized with low natural frequencies and mechanical damping are particularly sensitive to wind effects. It is therefore required to carefully analyze their aeroelastic behavior of during construction and exploitation. Scanlan and Tomko [1] proposed an original method for extracting the eight dimensionless flutter derivatives (FD), which can be thought as the contributions to the structural matrices and are considered to be the indicators of aeroelastic stability of bridges. Efforts are made to simplify this procedure recently, see [2]. In most cases, short bridge-deck section is suitable for the determination of aeroelastic behavior of a prototype bridge, see [3]. Even though some new methods for the determination of flutter derivatives are developed, [4], the wind-tunnel experiments and subsequent FD extraction methods are still the most utilized tools. In the present work, a comprehensive experimental study on dynamic behavior of Kao Pin Hsi bridge-deck section exposed to wind is carried out by using the multipurpose experimental setup for advanced aeroelastic tests. Obtained flutter derivatives are compared with those of the thin flat plate which is aeroelastically stable with respect to flutter phenomenon.

Description of the experiments

The wind tunnel experiments were carried out in the Climatic Wind Engineering Laboratory of the Centre of Excellence Telč, Czech Republic. The aerodynamic section of the tunnel is rectangular cross-section 1.9 m wide and 1.8 m high with an airflow velocity range from 1 m/s to 33 m/s. The flutter susceptibility is studied for the Kao-Pin-Hsi Bridge in Taiwan. This bridge has the main span length of 330 m. The wind-tunnel model of this bridge section is a 1:100 scaled-down model, with a width of 350 mm and length of 560 mm. This model is tested using an original and multipurpose experimental setup developed in the Centre of Excellence Telč, see [5]. The setup is designed and constructed for the purposes of quick measurements of both linear and nonlinear aeroelastic phenomena, as it enables quick and precise frequency tuning, where the heave motion is independent of pitch. Wind velocity is measured using the Pitot tube located upstream from the model and inside the plexiglass casing covering the frame of the stand and providing the 2D flow around the model. Flutter derivatives are obtained by using the free vibration method for the double-degree-of-freedom (DDOF) system, therefore initial excitation in both the heave and torsional motion is made and free decay oscillations are recorded. The bridge-deck section and flat plate dynamic response for a given velocity is obtained and analyzed by using the Unified Least-Square (ULS) method in order to derive effective damping and frequency, [6].

Results and discussion

Eight flutter derivatives, four generalized stiffness and four generalized damping coefficients, are obtained by the means of the DDOF coupled dynamic response of the bridge-deck section. Flutter derivatives obtained for the bridge-deck section are compared with the experiments on the flat plate, which represents an aerodynamically stable profile not susceptible to flutter, Fig. 1. Derivative H_1^* is associated with aerodynamic damping in heave motion, while A_2^* derivative is related with aerodynamic damping in torsional motion.

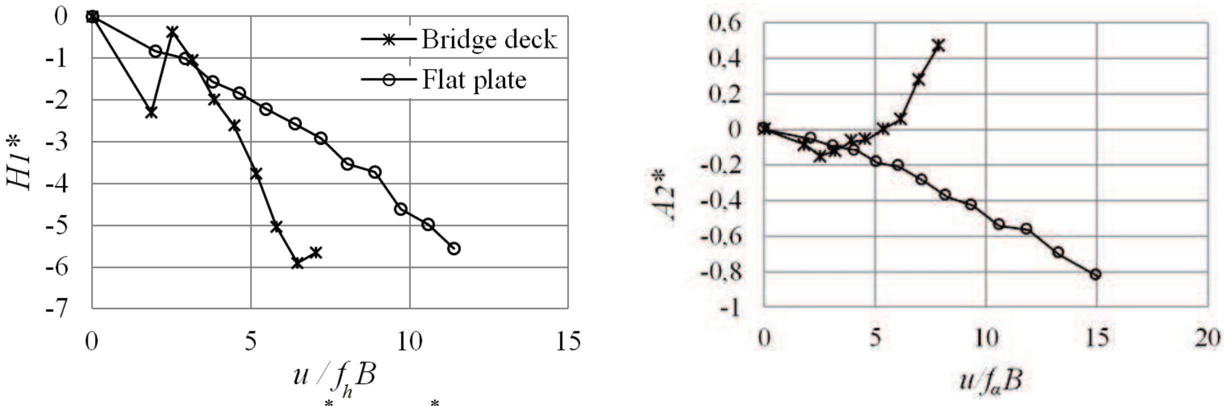

Fig. 1: Comparison of H_1^* and A_2^* derivatives for the bridge-deck section and flat plate, u is flow velocity in m/s, f_h and f_α are frequencies of oscillation for heave and pitch motion in Hz, B is the model width in m.

Even though the trends observed indicate that the investigated bridge-deck section has a stronger aerodynamic damping in the heave direction, it can be observed that the torsional instability characteristic (derivatives A_2^* crossing zero) for the bridge does not occur for the flat plate. In addition, the bridge-deck section experiences stronger shifts in the natural frequency of the pitch motion.

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