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Aero-structural design optimization of long-span bridges: From linear to nonlinear aeroelasticity-driven perspectives

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ABSTRACT

Structural optimization techniques have been demonstrated to be a powerful tool for the cost-effective design of bridges under aeroelastic considerations, particularly when applied to super-long span suspension or cable-stayed bridges. The efficacy of this methodology relies on the comprehensive and accurate formulation of the wind-resistant design problem. The analysis of the wind-induced responses, such as flutter and buffeting, has been typically addressed in the industry by
adopting multi-mode analysis techniques using linear force modeling approaches based on the fundamental contributions of Prof. Davenport and Prof. Scanlan. In the same way, the aero-structural
optimization frameworks previously developed by the authors have followed this approach by mimicking the design goals and specifications of real bridge projects in the formulation of the optimization problem. However, wind tunnel tests and on-site monitoring measurements have shown that under some circumstances, the so-called linear aeroelasticity models fail in predicting the bridge
responses. Hence, several nonlinear aeroelastic methods have been developed in the last decades, including the corrected quasi-steady theory (QST) model, band superposition model, hybrid nonlinear model, rheological model, artificial neural networks (ANN) based model, and Volterra models, among others. These methods should be advanced in order to define deck shape-dependent accurate models that permit their implementation into design optimization frameworks to achieve cost-effective and safe bridge design. This study reviews the effectiveness of these methods and discusses
practical directions to follow to adequately implement nonlinear aeroelasticity features into the holistic aero-structural optimization of long-span bridges.

Keywords: Aero-structural optimization, flutter, buffeting, nonlinear aeroelasticity, deck shape.

1 INTRODUCTION

The design of bridges has evolved in the last two centuries with the advances in structural analysis techniques and wind load modeling capabilities (Gimsing and Goergakis, 2012). The increasing length of the main spans of the long-span bridges built in the last century has turned the wind-induced loads into the governing design load. Advances in finite element modeling (FEM),