Changing Bridge Aerodynamics under Nonstationary Winds

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Abstract

The nonstationary features of winds during tropical cyclones and non-synoptic events have been recently observed and analysed. However, the significance of nonstationarity in the consideration of wind load effects has not been extensively investigated yet. The effects of nonstationarity on bridge aerodynamics could be discussed from both linear and nonlinear viewpoints. In this study, the effects of nonstationarity on the bridge aerodynamics have been investigated based on a semi-empirical linear, hybrid and generalized hybrid models, where the significant contribution of the time-varying mean wind speed to the effective angle of attack and hence to the nonlinear bridge buffeting response is highlighted. The results demonstrated the important effects of the transient nature on the nonstationary wind-induced structural response. This study could facilitate more appropriate design of flexible structures considering non-synoptic or tropical-cyclone wind loads.

Keywords: Nonstationary; nonlinear; bridge aerodynamics; buffeting.

1 Introduction

The assurance of bridge safety and reliability under extreme winds requires accurate modelling of wind-induced effects on bluff structures. This heavily relies on our understanding of the nature of tropical cyclones and non-synoptic winds (characteristics of wind inputs) and bluff-body aerodynamics (from wind inputs to load outputs), and their potential interactions.

Within the traditional analysis framework, approaching wind fields are usually simplified as a steady flow part, which is characterized by the constant mean wind speed and profile, and the zero-mean fluctuating flow part, which is characterized by statistical properties such as turbulence intensity and integral scale, gust factor, peak factor, probability distribution and power spectrum. Recent measurements of the wind field during tropical cyclones and non-synoptic events indicate that the wind fluctuations exhibit strong non-stationary features (e.g., Wang et al. 2016). There is a trend (time-varying mean values) in a typical nonstationary wind process. Accordingly, the definition of statistical properties needs to be updated so that the time-varying mean values could be naturally integrated. A nonstationary wind model, in which the constant mean wind speed is replaced by time-varying mean values, is an effective tool for this purpose (Xu and Chen 2004). Nonstationary wind data is usually characterized not only by the time-varying mean values but also by time-dependent amplitudes that may be modelled in simple cases by an envelope function. In some cases, these features may be frequency-dependent, which influence the power spectral density (PSD).

The significance of nonstationary considerations in the aerodynamic load effects due to extreme wind events has been demonstrated by several researchers (e.g., Cao and Sarkar 2015). However, most of current research on wind effects on buildings, bridges and other structures during tropical cyclones and non-synoptic winds are fully dependent on the conventionally identified

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