IABSE SYMPOSIUM ISTANBUL

LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL
ATAKOY HOTEL

Paper ID: 3774
Nonlinear buffeting response of long suspension bridges considering parametric excitation due to large-scale turbulence

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ABSTRACT

The accurate modelling of self-excited forces for long-span suspension bridges is known to be very important for both the assessment of the flutter stability and the calculation of the buffeting response to turbulent wind. It has also been proved that self-excited forces often parametrically depend on variations of the angle of attack, which can easily be induced by large-scale turbulence. A nonlinear buffeting model is outlined here to explore this issue, emphasising the influence of nonlinear turbulence effects on the stresses in the main structural elements and not only on displacements and accelerations of the bridge deck. The proposed approach is based on the 2D Rational Function Approximation model for self-excited forces, recently developed and experimentally validated by the authors. Despite the complexity of the problem, this model only slightly changes the dynamic equations based on the linearised theory, making it friendly to be implemented. The Hardanger Bridge, in Norway, is chosen as a case study, as its aerodynamic derivatives strongly depend on the angle of attack. The contribution of the wind load to the internal forces in the main cables and in the hangers is found to be only marginal. In contrast, the stresses induced in the deck girder are large, and the results for high wind speed emphasise the strong impact on the torsional moment of the modulation of the self-excited forces due to the spatio-temporal fluctuation of the angle of attack produced by low-frequency turbulence.

Keywords: Nonlinear buffeting, self-excited forces, angle of attack, wind-induced stresses.

1 INTRODUCTION

Over the past three decades, the number of long-span suspension bridges has more than doubled with no sign of stopping, as also suggested by some recent national infrastructural large projects (e.g., the Norwegian E39 fjord crossing project [8]. Wind-induced effects might be crucial for such slender structures, and the dynamic response due to turbulent wind (buffeting may even govern the structural design. Indeed, suspension bridges are low-damped structures, and the overall response is mainly due to resonant contributions associated with several low-frequency modes. As a consequence, a crucial role is played by the aerodynamic damping produced by motion-induced forces (self-excited forces,

https://doi.org/10.2749/istanbul.2023.0351