Spatial variability effects of the seismic action in Cable-Stayed Bridges and modelling techniques

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Abstract

This paper presents different modelling techniques to account for important interaction effects between the deck, the cable and the towers in cable-stayed bridges with different configurations and main span lengths under strong ground shaking. The model of the connection between the deck and the tower is optimised in terms of accuracy and computational cost, proposing a link that allows for both mode-based and direct integration analysis. The importance of the cable-structure interaction is discussed from the point of view of the vibrational properties and the nonlinear seismic response. The discussion is extended to the influence of the lack of synchronism of the seismic excitation in three cable-stayed bridges with 200, 400 and 600m main span, presenting an extensive study on the seismic demand of the towers for different wave-front propagation velocities.

Keywords: Cable-stayed bridges; tower-deck-cable interaction; Finite Element Models; modelling techniques; vibration modes; seismic action; spatial variability.

1 Introduction

Cable-stayed bridges represent important points within infrastructure networks which span distances unsurmountable in the past. Due to their large flexibility, reduced weight and low damping [1], these structures are prone to vibrations and their design is usually governed by dynamic actions such as earthquakes or wind. In order to obtain realistic results in the design stage, the mass, stiffness and damping of the cables the deck and the towers should be modelled rigorously, as well as the interaction between them.

The connection between the deck and the towers represents a key factor in the static and dynamic behaviour of cable-stayed bridges [2]. The design of this connection should be a compromise solution between two extreme cases: (1) the deck is completely released from the towers (floating connection), reducing the seismic action in the towers but leading to potentially excessive displacements or instable responses in the deck under wind loading, or (2) the deck is completely fixed to the tower, reducing the displacement but enlarging the seismic demand in the towers. The current trend in cable-stayed bridges located in seismic areas is to connect the tower and the deck with auxiliary devices in horizontal direction (parallel and/or perpendicular to the traffic) that concentrate the seismic demand and leave the tower in elastic range even under severe ground motions.

A distinguishing characteristic of the dynamic behaviour of cable-stayed bridges is the cable-structure interaction. The vibration of the cables can transfer energy between the deck and the towers, reducing the structural response under broadband frequency excitations. However, if the structure is subjected to earthquakes with specific dominant frequencies the effect could lead to problematic amplifications of the seismic response [3]. Several authors propose Finite Element (FE) discretisations with Multiple-Element Cable-Systems (MECS), instead of the traditional One-Element Cable-System (OECS), to capture the local vibration of the cables [4].However, in the study on the Ting Kau bridge (Hong Kong) it was observed that only the local vibration of the longest cables (465 m long) can slightly affect the global vibration periods and must be modelled with greater detail (MECS), while for shorter cables the global dynamic response of the bridge

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