Nonlinear Behaviour of Under-Deck Cable-Stayed Bridges with Steel–Concrete Composite Decks

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Abstract

The effect of geometric nonlinearities in the response of under-deck cable-stayed bridges with steel–concrete composite decks is studied. Influence lines for deflections and bending moments at different sections of the deck are obtained, and these are found to be different to those for conventional bridges. Nonlinearities affect principally the response of lateral subspans, in which both deflections and bending moments are amplified. The permanent state should be studied by taking nonlinearities into account. Deflections under further loads can be obtained with linear models. Geometric nonlinear effects increase design bending moments under ultimate loads by 12% when compared with linear models. Some additional design criteria for designers aiming to design under-deck cable-stayed bridges are hence provided.

Keywords: bridges; cable-stayed; innovative cable-staying systems; under-deck cable-staying systems; nonlinear response; composite construction.

1 Introduction

Since the late 1970s, a new type of cable-stayed bridge has been designed and built: under-deck cable-stayed bridges (UDCSBs) [1]. In UDCSBs, the stay cables are located underneath the deck, see Figure 1. The pre-tensioned stay cables, which are self-anchored within the deck, provide elastic supports to the deck by means of the struts, reducing the bending moments acting on the bridge as a consequence.

UDCSBs have been reported to present several advantages in comparison with conventional bridges without stay cables for medium spans [2]: (1) highly efficient structural behaviour by reducing the flexural demand on the deck and enhancing the axial response; (2) significantly higher deck slendernesses can be achieved; (3) smaller amounts of material are required, consequently allowing for a more sustainable design; and (4) multiple construction possibilities. Moreover, UDCSBs present, arguably, strong aesthetic characteristics and are an entirely appropriate solution when there is sufficient clearance to install the stay cables.

UDCSBs present many analogies with bow-string arches. Indeed, the former can be considered as an inverted bow-string arch, in which the tensioned deck of the arch becomes the compressed deck of the UDCSB and the compressed arch becomes the tensioned cable-staying system of the UDCSB. Both bridge typologies present higher flexibility under

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