A higher order finite element to analyse steel-concrete composite bridge decks

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Abstract

This paper presents a novel interdependent interpolation finite element for a higher order beam model capable of capturing the shear-lag phenomenon and the overall shear deformability of composite beams. After a brief overview of the beam kinematics and of the differential solving equations, the stiffness matrix and the nodal forces to be used in a standard finite element procedure are derived in a consistent way by exploiting properties of exponential matrices and their application in the solution of linear differential equation systems. Some comparisons with solutions obtained by using finite elements with polynomial interpolating functions demonstrate the capability of the new element.

Keywords: Composite bridge decks, exponential matrices, finite elements, interdependent interpolation, shear deformability, shear-lag.

1 Introduction

The analysis of composite beams, especially in the cases of continuous bridges, ought to capture the shear-lag phenomenon and the effects of the overall shear deformability that are responsible for non-uniform strain distribution within the cross section and for additional displacements that, despite the usual deck slenderness, are rather significant [1, 2]. Thus, an accurate evaluation of the beam deflection, forces on the connection, and stresses on the slab and steel beam, cannot be obtained with traditional beam theories based on the assumption of the preservation of the plane cross section. The use of shell finite elements permits to obtain accurate solutions but results are not synthetic and have to be heavily post-processed for design purposes. As an alternative to finite element models based on planar elements, the analysis can be performed with higher-order beam models able to capture the effects of the deformable connection, the shear deformability of the overall cross section and the shear-lag produced by the warping of the slab and steel beam cross-sections.

In this framework, a higher-order beam model has been proposed by Dezi et al. [3] starting from a generalisation of the Newmark model [4] and accounting for the overall shear deformability of the components [5] and the warping of the slab cross section and the steel beam [6].

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