Lateral Dynamic Models for High-Speed Railway Bridges and Vehicles

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Summary

The analysis of the running safety of railway vehicles on viaducts subject to strong lateral actions such as cross winds requires coupled nonlinear vehicle-bridge interaction models, capable to study extreme events. In this paper original models developed by the authors are described, based on finite elements for the structure, multibody and finite element models for the vehicle, and specially developed interaction elements for the interface between wheel and rail. The models have been implemented within ABAQUS and have full nonlinear capabilities for the structure, the vehicle and the contact interface. An application is developed for the Ulla Viaduct, a 105 m tall arch in the Spanish high-speed railway network. The dynamic analyses allow obtaining critical wind curves, which define the running safety conditions for a given train in terms of speed of circulation and wind speed.

Keywords: vehicle-bridge interaction, bridges, nonlinear, dynamics, finite elements, multibody, cross winds, critical wind curve.

1. Introduction

Crosswinds induce significant lateral forces on vehicles, which may endanger the safety of high-speed railway traffic on viaducts. On the one hand, wind velocity is higher for tall viaducts crossing deep valleys. On the other hand, the lateral flexibility of the structure may introduce significant coupled effects, which increase the dynamic action [1]. The importance of dynamic coupled effects for trains on bridges was demonstrated and studied by the ERRI D181 committee [2]. The ERRI D181 study focused on bridges of simply supported type, with spans around 50 m, and generally with open steel structure decks and low lateral stiffness. The conclusions of this study were the base for a design rule limiting the lateral flexibility of bridges in the Eurocode EN 1990-A1 [3]. The types of viaducts of primary concern for this work have important differences with those considered in the ERRI study. They are also very flexible laterally, but with much higher wavelengths of the deformation modes. In this work we apply an original model for the nonlinear coupled dynamics of vehicles and bridges to tall and slender viaducts, which are common in high-speed railway lines. These viaducts introduce two concerns which motivate the study: high cross- winds due to the height in the valley, and a low lateral stiffness with eigenfrequencies below 0.5 s.

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