Development and validation of a train-bridge interaction model

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Abstract

In this paper, a train-bridge interaction model is presented to simulate the behaviour of a bridge during the passage of a train. Two modelling methods are compared: the direct integration method (DIM) and the intersystem iteration method (ISIM). First, a simply supported bridge subjected to a moving spring-mass is modelled using both methods and validated with an analytical solution. Subsequently, incorporating damping into the model adds an extra layer of complexity, rendering the search for analytical solutions unfeasible. The validation of the more complex models is accomplished by comparing them to similar simulations documented in the existing literature. The focus lies on finding an efficient model that could be used by engineers to assess the structural condition of railway bridges. The dynamic interaction model gives a more accurate prediction of the behaviour of the bridge under the passage of the train than including the dynamic amplification factor (DAF) in the static calculation.

Keywords: wheel-rail interaction, direct integration method, intersystem iteration method.

1 Introduction

The European project 'Sustainable bridges' [1] highlighted how sustainability is becoming more important in the (re)construction of railway bridges. The goal is to have a modal shift in the use of transport and stimulate people to prefer public transport or the bicycle instead of the car. Therefore, public transport options must become more attractive. Especially for rail transport, the capacity and the number of trains should be increased. The focus of the European project lies on Railway bridges wherefore it is not directly possible to enlarge the railway network, so the quantity of train passages will be enlarged. By increasing the capacity of the trains, the axle loads will become larger and result in a shorter end-of-life span of the railway bridges. To guarantee the safety of the design, measurements and safe life predictions of the railway bridges must be performed. To reduce the uncertainty on fatigue life predictions, more accurate structural assessments are required. Typical evaluations are based on quasi-static stress calculations enlarged with a dynamic amplification factor. With this method stresses due to local dynamic modes are ignored resulting in underestimation of the stress or in other cases the DAF is overly conservative. Hence stress calculations that account for the actual structural dynamics would lead to more accurate fatigue life estimates.

2 Importance of a dynamic interaction model

The research of dynamic wheel-rail interaction models dates back to 1949 when Willis and Stokes [2] perform real experiments of a moving mass over a simply supported beam. In their study, they compared the vertical deflection at midspan of the beam, for various velocities V of the mass, with the vertical deflection caused by a beam loaded with a static point load the midspan. Figure 1 illustrates the vertical deflection at midspan observed in the experiment.

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