

Abstract

The technical progress in the construction of railway bridges enables the realisation of more and more slender and lightweight structures. Simultaneously, the capacity of the operating trains is constantly increased, which results in higher axle loads and faster travelling speeds. Caused by these developments, the dynamic behaviour of railway bridges is getting more and more important for the design and construction of new structures or refurbishment purposes. By means of the calculation methods currently used in practice, the dynamics of railway bridges under the impact of moving trains can often not be predicted with satisfying accuracy. This problem particularly holds true for short bridges with ballast superstructure, so that in-situ tests and measurements have to be carried out which acquire considerable operating expenses. In calculating the dynamic response of bridges two aspects play a decisive role: the detailing of the analytical models and the realistic estimation of their damping. These are the two key aspects of the present work.

Referring to the creation of analytical models the problem is constricted to transverse vibration of beam bridges including the effects of rotatory inertia and shear deformation. Starting with a strict derivation of the equations of motion the method of *Ritz* and *Galerkin* (in particular modal analysis) is used to discretise the bridge. The vehicles are described using three different analytical models: a series of moving forces, a series of moving masses and a series of multi-body systems. The load models are interacting with the bridge via contact forces to simulate vehicles crossing the bridge. The resulting equations of motion are solved by means of numerical methods. An application program has been written basing on the programming language MATLAB, which enables the user to calculate the dynamics of vehicles crossing bridges automatically using the load and bridge models covered in this work. The three load models are compared with each other using worked samples related to practice. The results show clearly that the dynamic response of a bridge is overestimated if the load models consist of concentrated forces or masses, whereas with load models consisting of multi-body systems more accurate results can be achieved.

Moving forces are well suited to calculate the dynamic response of railway bridges approximately if the interaction between the vehicles and the bridge is covered with additional damping. Response spectrum analysis, which has proved itself in structural dynamics, is adopted to calculate the dynamic response of bridges under moving forces. With the aid of response spectra developed in the present work, the maximum dynamic response of a bridge can be determined without the need of costly computation.

In the second key aspect of the thesis the influence of the ballast superstructure on the transverse vibration of railway bridges is analysed. To investigate the dynamic interaction between

the ballast superstructure and the structure of the bridge an experimental bridge has been built. The experimental bridge is set up as a single span bridge made of steel with 10 m in length and is equipped with sensors to measure accelerations and displacements. Thereupon a full size assembly of ballast substructure is mounted. The dynamic properties of the experimental bridge were tested without and with ballast superstructure. An innovative system of two eccentric weight vibration generators was used basing on the methods of experimental modal analysis. With this approach the contribution of the ballast superstructure to the dynamic behaviour of the whole bridge can be quantified exactly. The experiments show that the ballast superstructure affects the damping and the dynamic stiffness of the bridge in a nonlinear way. The ballast superstructure is modelled mathematically using a beam which is coupled to the beam describing the bridge structure, so that a system of two coupled beams is created. Consequently, the mathematical model of the ballast superstructure can also be applied to other beam bridges, which is demonstrated in a concluding example. There, it becomes apparent that the knowledge of the effects of the ballast superstructure is of great importance when the dynamic response of railway bridges under moving loads is sought. The vibration characteristics of the bridges can be estimated more precisely.