Design of Computer Models for Describing the Dynamic Behaviour of the Ballast Substructure of Railway Bridges

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Summary

In this paper the most actual research results of investigating the dynamic behaviour of the ballast substructure of railway bridges are shown. Especially the stiffness and damping properties of the ballast will be discussed. The intention of these investigations is to create a computer model with determined parameters, describing the behaviour of railway bridges in order to make possible detailed, fast and efficient dynamic calculation for this type of bridges.

Keywords: railway bridges, ballast substructure, dynamics, damping

1. Introduction

Remarkable dynamic stress is caused by today's high-speed traffic in railway infrastructure. The European standards [1] request a dynamic calculation of railway bridges under high-speed traffic. But a model for calculation it is not given in detail. Moreover the damping parameters are defined very conservatively.

In a research project of the Institute of Structural Engineering – Research Center of Steel Structures, the dynamic behaviour of the ballast substructure of railway bridges has been investigated. The first step was constructing an experimental bridge in the laboratory. Some facts are given here: The bridge has a span of 10 meters, two main beams HEA 340 connected with crossbeams in the quarters and a wooden track deck on it, carrying the ballast substructure and the track.

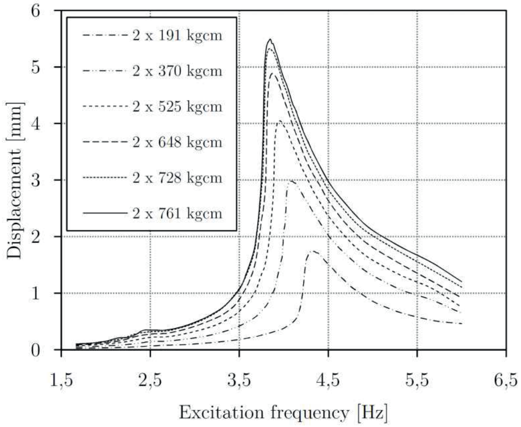

Fig. 1: Frequency response for different me

Two vibration generators induced a harmonic dynamic excitation to the bridge. The harmonic force of the vibration generators is shown in equation (1).

$$P_{(t)} = me\ \Omega^2 \sin \Omega t \quad (1)$$

In this paper the product of me (eccentric- mass m × eccentricity e) is defined as a marking of the value of excitation. The frequency response for different excitations was measured, the results are given in figure 1. Mähr [2] found out that the ballast substructure is part of the dynamic behaviour and its rate is not negligible. Higher stiffness of the experimental bridge in comparison to the calculated one was shown. This fact is caused by the ballast. These results are the basis for finding parameters, describing the dynamic behaviour with the developed computer model which is described by the following details.

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2. Computer Model to design the ballast substructure

The used model consists of vertical couplers between the rail and the bridge deck. The couplers next to each other are connected diagonally with spring and damping elements (fig. 2). In this way the transfer of the shear forces and the damping of the ballast substructure is simulated. For detecting the parameters of the dynamic elements a finite element model was used [3].

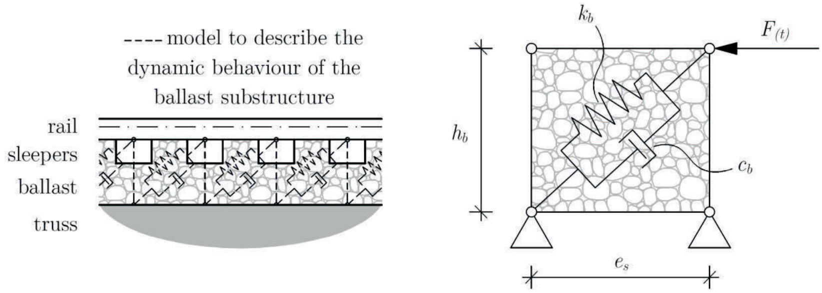

Fig. 2: Model of the ballast substructure and its parameters

A basic finite element model of the experimental bridge combined with the model for the ballast substructure was adapted to the measured results. The results are shown in table 1.

Tab. 1: Parameters of the ballast substructure

me	2 x 191	2 x 370	2 x 525	2 x 648	2 x 728	2 x 761	[kgcm]
f	4,316	4,083	3,950	3,866	3,850	3,850	[Hz]
k_b	14055	11345	9930	9080	8915	8915	[kN/m]
c_b	94,60	97,00	95,76	94,32	96,62	97,78	[kNs/m]

There the stiffness of the spring elements is marked with k_b and damping elements with c_b. These identified parameters belong to the first eigenfrequency f. It is recognizable that the value of the stiffness k_b is decreasing with the rising of the excitation me. For this behaviour the following cubic equation (2) can be given:

$$k_b = 0{,}003(me)^2 - 11{,}61\,me + 17940 \quad (2)$$

Equation (2) will be used for further calculations on an operational bridge to convert the parameters for other excitations me. The parameter for damping c_b fluctuates approximately around the mean value of 96,0 kNs/m.

3. Conclusion

The presented model is able to simulate the behaviour of the experimental bridge. Dynamic parameters describing the behaviour of the ballast substructure were found. Further investigations of operational bridges using the detected parameters for the ballast substructure will show if the modeling is exact enough for a practical application. Then the aim of a detailed, fast and efficient dynamic calculation of railway bridges will be reached.

4. References

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