Dynamic Investigation of a Filler Beam Railway Bridge for High-Speed Trains

Author: Bárbara Evaldt Bombardelli
Supervisor: Dr.-Ing. habil. Volkmar Zabel

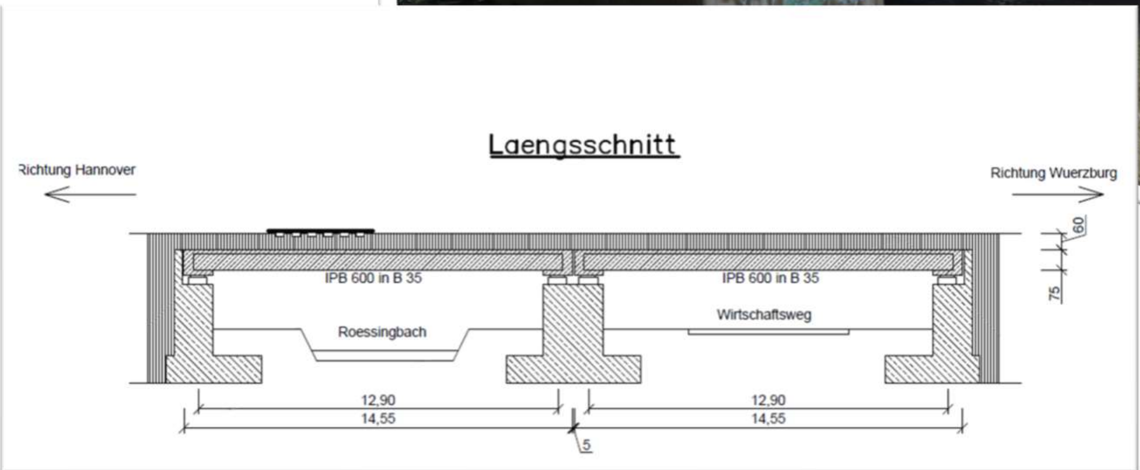
Introduction

Railway bridges dynamics involves the response of the bridge to the movement of vehicles and the influence of a number of parameters which can increase the dynamic strain and stresses, such as frequencies, damping, train speed and track irregularities.

In bridge design, the Eurocode requires a dynamic analysis in some cases, and in general for bridges for trains of higher speed than 200km/h, if its necessary, the analysis should include the high-speed load models (HSLM).

For this study, an existent composite filler beam bridge with ballasted track was investigated, through a numerical model and dynamic simulations using modal superposition for different load models and train speeds. The dynamic response of the bridge was obtained, acceleration and displacement results were analyzed for critical speeds and compared to Eurocode standards.

The bridge



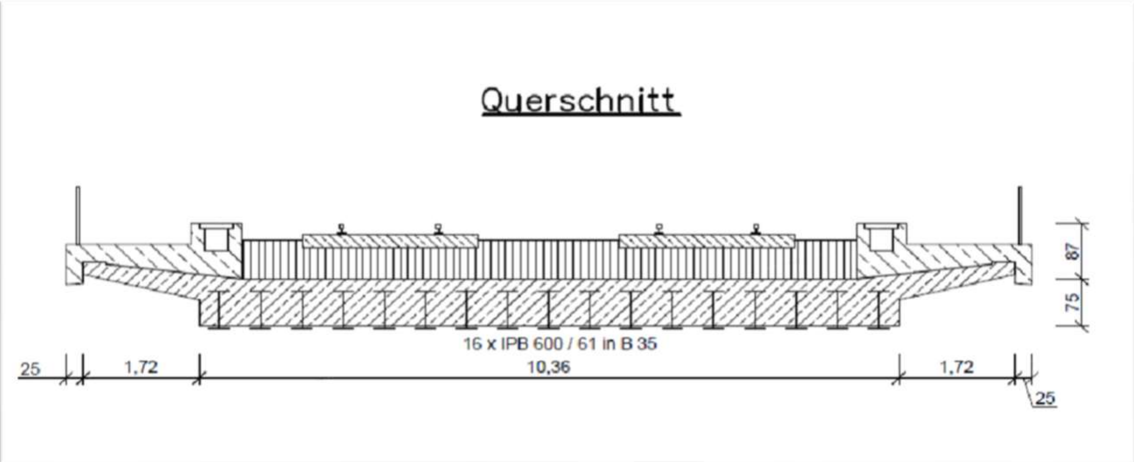
Up: Lateral view from the bridge at site (Zabel, V.)
Down: Longitudinal view from the bridge (Höll, S.)

The bridge

The bridge is a two-span composite filler beam bridge located in the Hannover-Würzburg high-speed railway line, in the district of Gießen.

The bridge was built between 1987 and 1988 and was designed to operate at a service speed up to 250km/h.

The bridge was designed with two spans of 12.9m in length and is constituted of reinforced concrete with rolled steel beams (IPB600), on top of the slab sits a 60cm ballast layer. The superstructure sits in two abutments, one at each end and a single pier between the two spans.



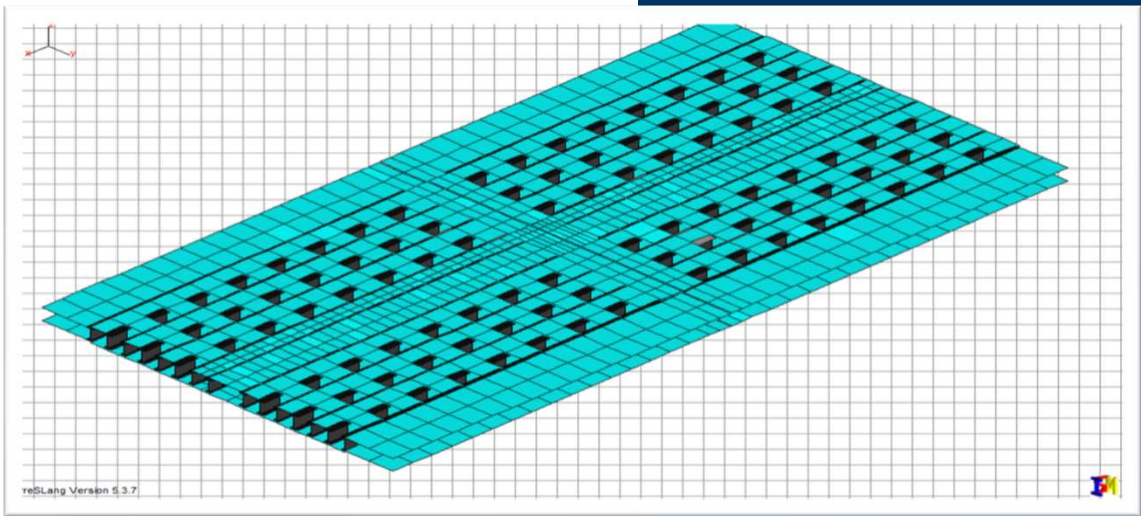
Cross-section of the bridge (Höll,S.)

FEM model

The bridge model was created using the graphical preprocessor PreSlang and afterwards concluded in the Slang finite element program.

The model was created with 9-nodes shell elements with layers for the concrete and ballast and with I sections for the steel beams. The structure has an expansion joint between the two slabs and was maintained in the design in the concrete layer, the ballast was taken as continuous through the two spans

To account for the support of the superstructure translational restraints were applied and rotational springs included.



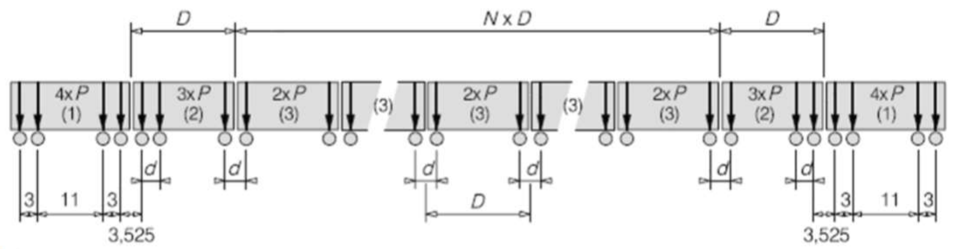
FEM Model in PreSlang

The train load model

The requirements for the dynamic analysis can be obtained in the Eurocode and are influenced by numerous points, depending on the characteristics of the bridge such as the natural frequencies and the maximum line speed at the site. In the case of a bridge designed for international European lines, a dynamic analysis is also required.

When it is required, Eurocode specifies the characteristic values of the train loads by the HSLM (High Speed Load Model) A and B, which represent the dynamic load effects of articulated, conventional, and regular high-speed trains.

The HSLM-A model is required for bridges with a span greater than 7m, for a simply supported span, a single model may be used, or all the specified, in this project all the HSLM-A models were used. The point loads varied from 170 kN to 210 kN.

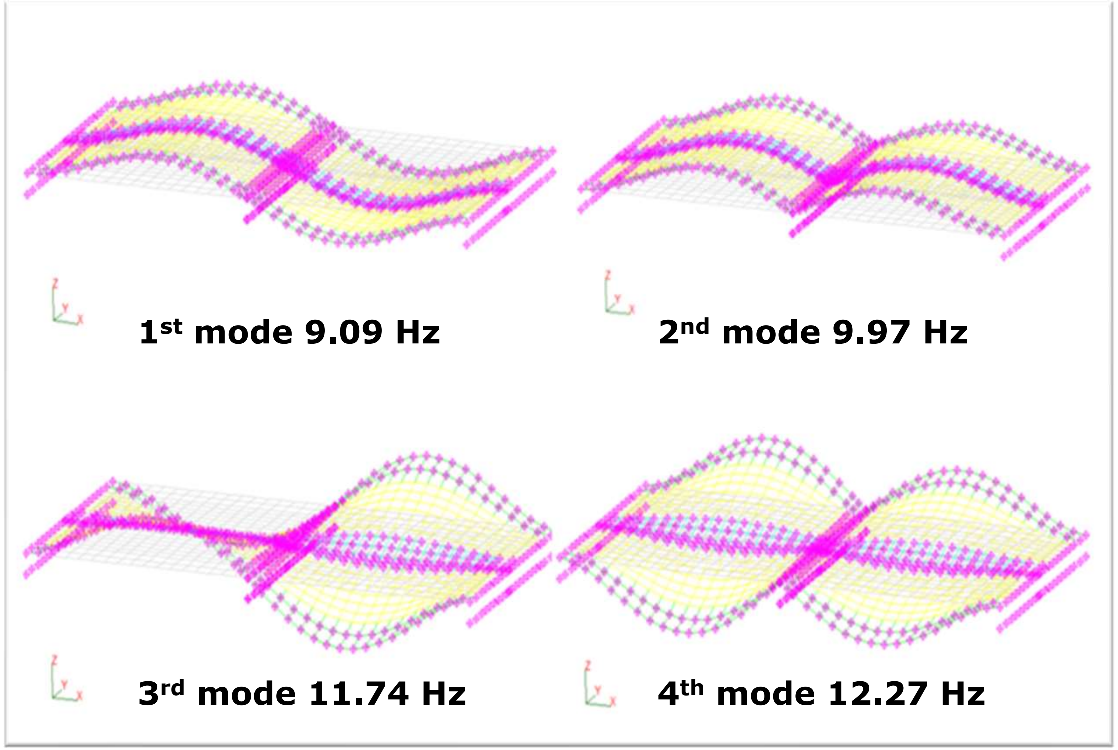


Key
(1) Power car (leading and trailing power cars identical)
(2) End coach (leading and trailing end coaches identical)
(3) Intermediate coach

HSLM Train Load Model

Eigenvalue analysis

The eigenvalue analysis was obtained in the software Slang from the FEM model created, with a damping ratio of 1.5%.



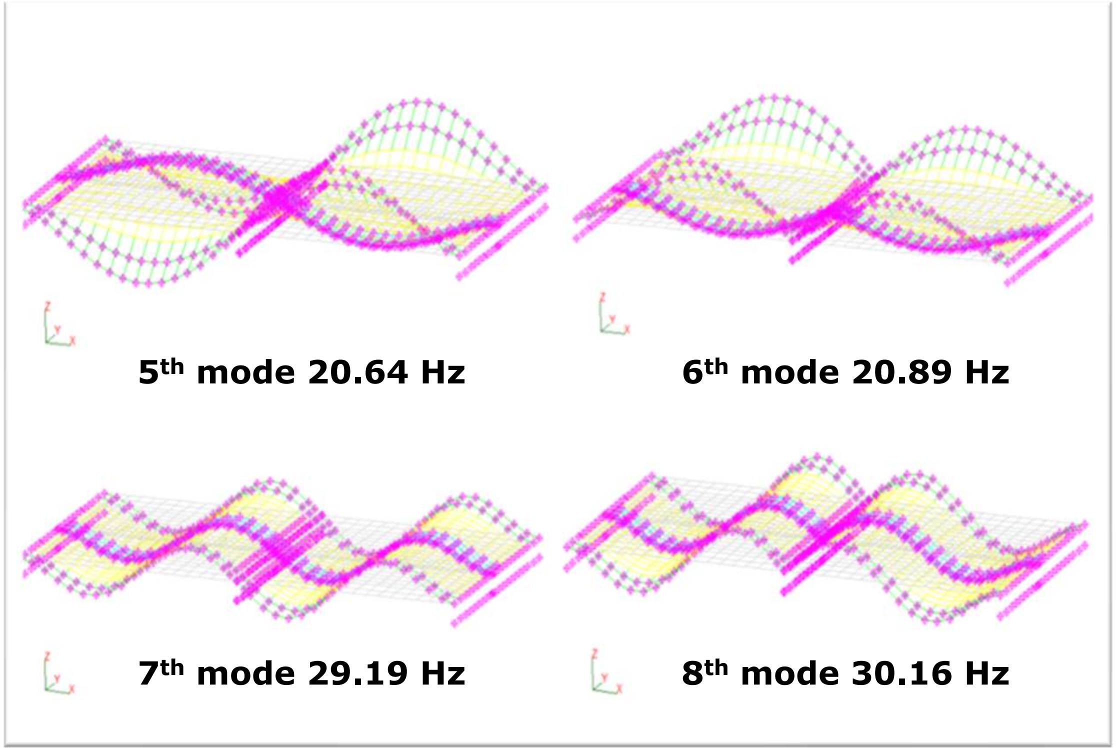
1st mode 9.09 Hz

2nd mode 9.97 Hz

3rd mode 11.74 Hz

4th mode 12.27 Hz

Eigenvalue analysis



Dynamic analysis

The results from the dynamic analysis for the existing bridge when subjected to moving loads (represented by the HSLM-A load models) are presented.

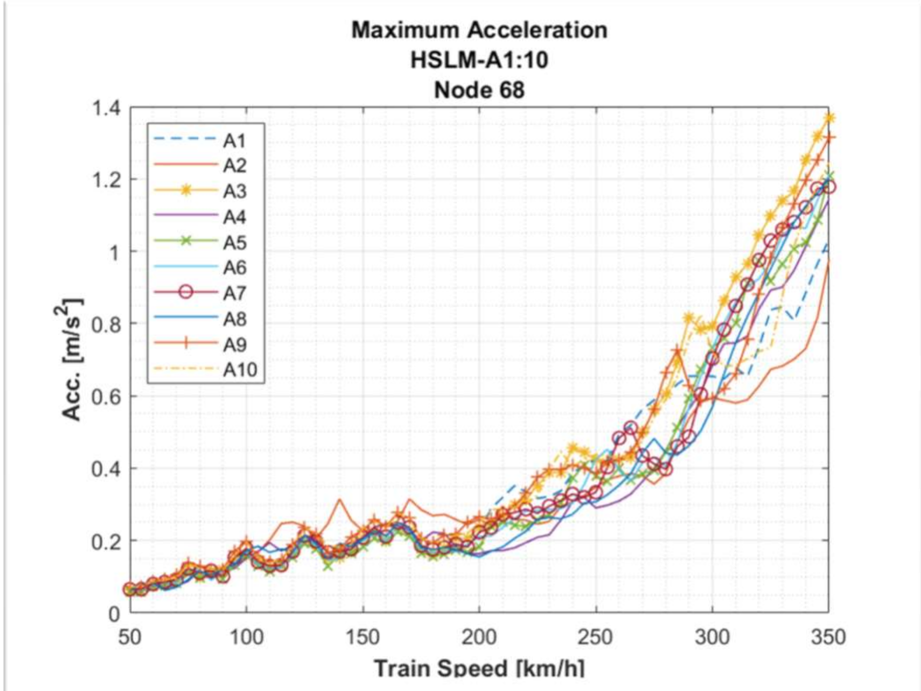
Values of acceleration and displacement were obtained through model superposition for several train speeds.

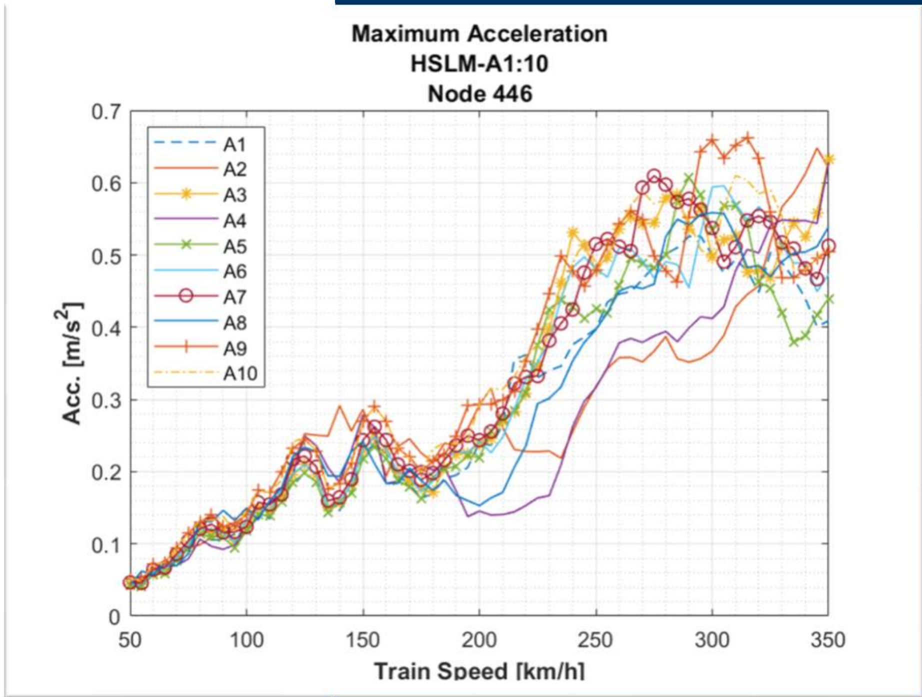
The results are shown for two locations, at half span (denoted as node 68) and at one quarter span (node 446).

The obtained results show an overall good behaviour of the bridge, with maximum acceleration values around 1m/s² and displacement around 2mm

Dynamic analysis

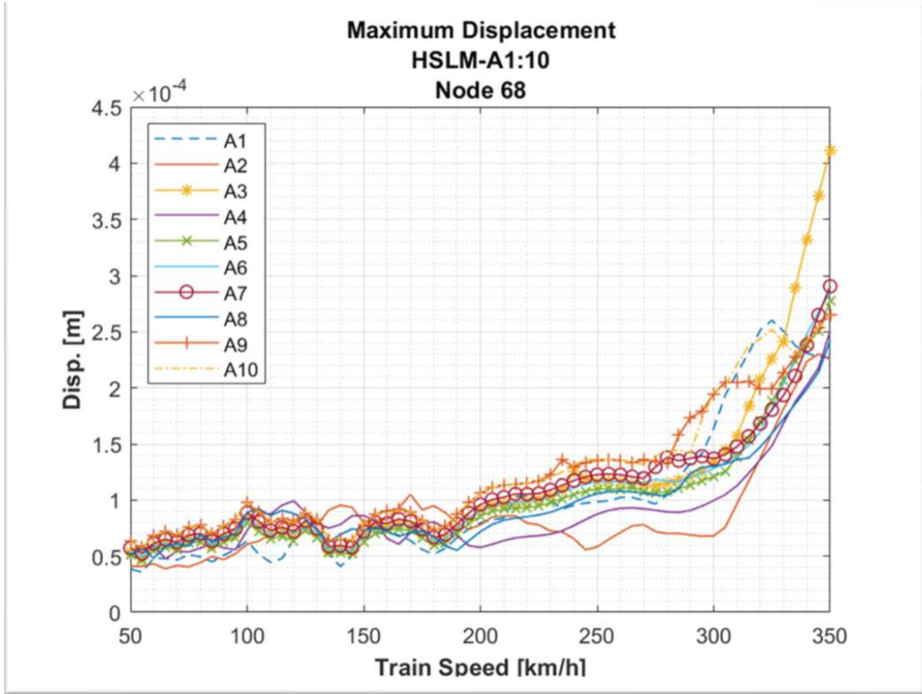
Acceleration

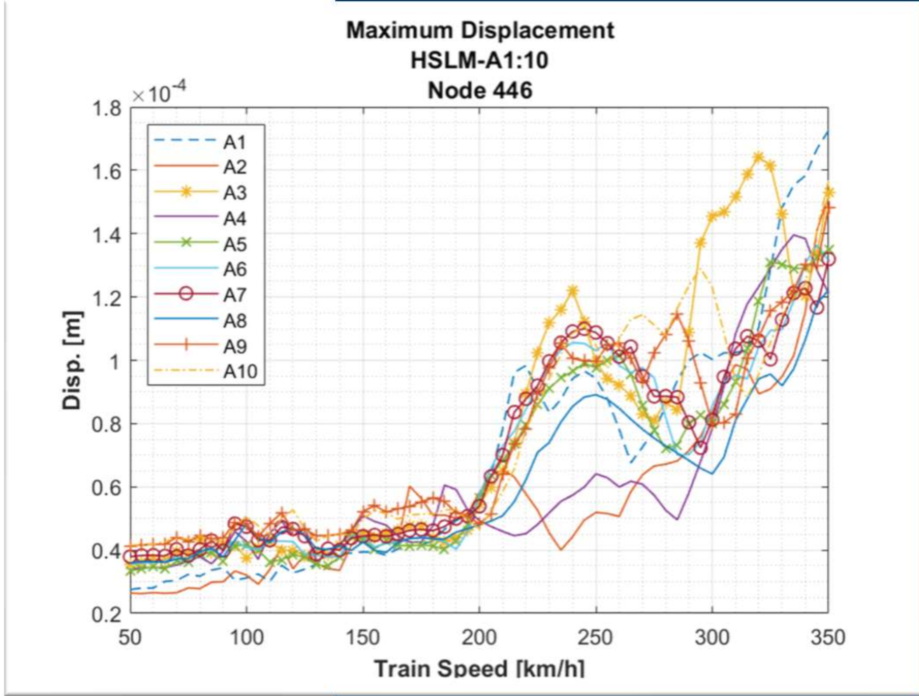




Dynamic analysis

Displacement





Conclusions

- The dynamic analysis reached good results, where both acceleration and displacement values are low, in agreement with Eurocode guidelines for the load models that the bridge was subjected.
- It is worth mention that train speed is important and directly influences the dynamic response of the railway bridge, and in general, the response increases with speed, but not only speed.
- Overall understanding of the structure including support conditions is necessary to create a reliable FEM model.

Conclusions

- Attention should be paid while defining the material properties for the numerical model as they play a major role in a more realistic reproduction of the bridge behaviour, such as the modulus of elasticity and poison ratio.

- Meanwhile ballasted bridges exist for decades, it was rather difficult to define the ballast properties as different materials can be used and are not always specified, and even in the literature different values were found.

Thank you for your attention!