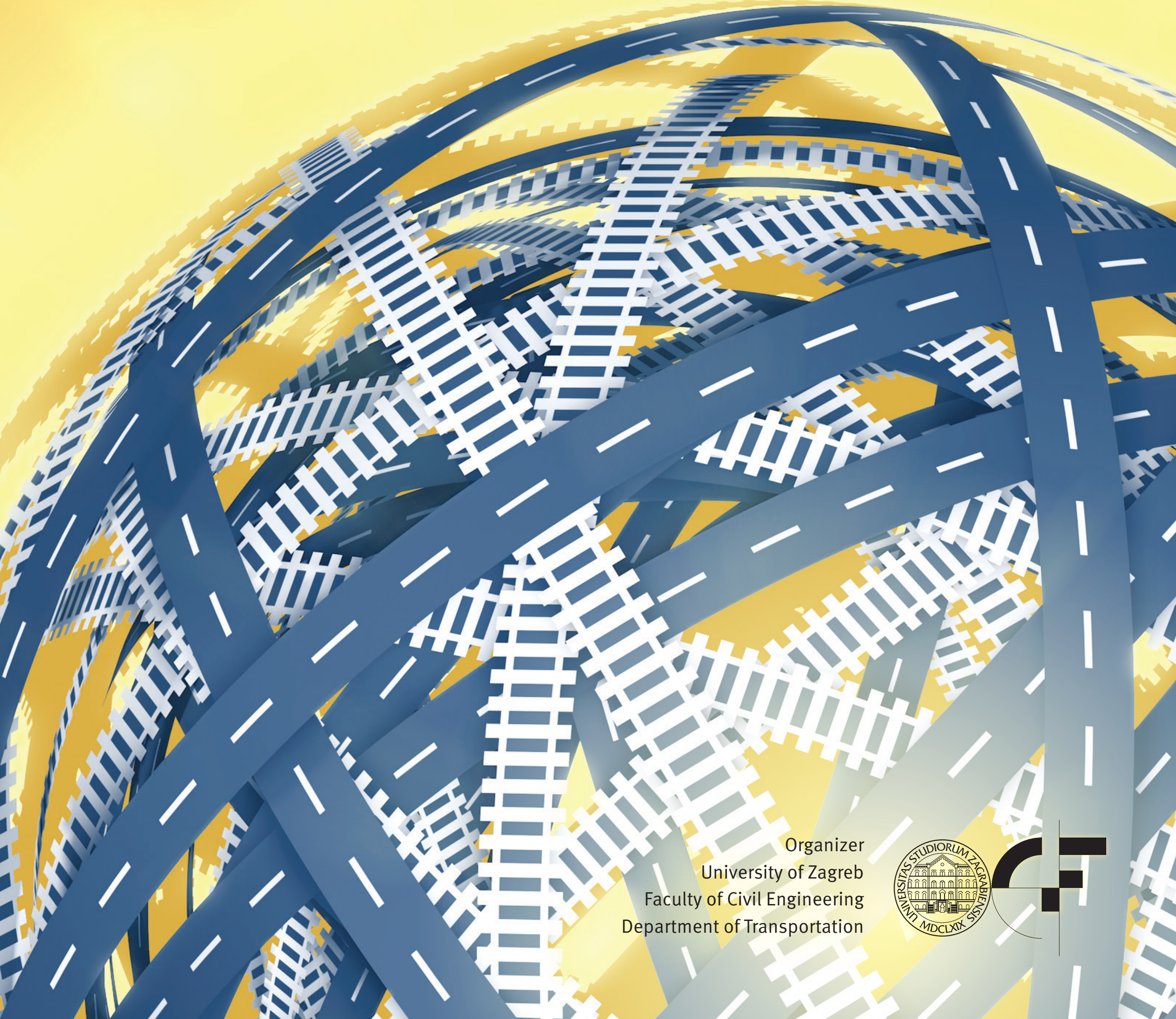
CETRA[2016]

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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THE INTERACTION OF STEEL RAILWAY BRIDGES WITH WOODEN SLEEPERS AND LOADED CWR TRACKS IN RESPECT OF LONGITUDINAL FORCES

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Abstract

If rails are constructed continuously over discontinuities (such as between a bridge deck and an abutment) without any rail expansion devices, the rails might restrain the free movement of the bridge, therefore longitudinal forces might be generated in the rails, in the bridge structure and the fixed bridge bearings. As a result of the interaction of steel railway bridges and continuously welded rail (CWR) tracks, normal force can be generated in the rails from the deflection of the bridge deck, from braking and acceleration of the trains and from change of temperature. Internal forces and displacements resulting from the change of temperature arise on an unloaded track. Effects from the braking and acceleration of the trains are generated on a loaded track. The longitudinal behaviour of a loaded and an unloaded track is basically different, therefore a non-linear computation has to be carried out on an unloaded and another one on a loaded track. Eurocode standard allows for the linear superimposing of results obtained from two non-linear models. This paper produces calculation methods for the combined response of CWR tracks and bridges in respect of longitudinal effects, without carrying out computations on two separate non-linear models. Recommendations are presented for the calculation of internal normal forces in the rails, bridge structure and the fixed bearing, and also that for relative displacement of the bridge and the rail.

Keywords: expansion joint, heat expansion, steel bridge, wooden sleepers, rail restraint, combined response

1 Introduction

A finite-element (FEM) model has been developed to determine the normal, axial forces in the rail, bridge structure and the bearing in case of a two-span-bridge with an expansion length of 40 m resulting from the change of temperature and braking and acceleration of trains. Following this, the model has been converted into bridges with 70 m and 100 m expansion.

2 Laboratory testing

Test series have been carried out in the Laboratory of the Department of Highway and Railway Engineering, Budapest University of Technology and Economics. The aim of these tests was to determine the longitudinal stiffness and the longitudinal rail restraint of Vossloh KS (Skl-12) fastening in case there was railpad under the railbase.

2.1 Longitudinal rail restraint tests without any vertical load

The tests were carried out according to standard EN 13146-1:2012 [1]. The test arrangement is shown in Figure 1. The rail displacement was measured with inductive transducer of type Hottinger Baldwin Messtechnik (HBM) WA20 mm and the load was measured with force transducer of type HBM C9B 50 kN. The data acquisition unit and measuring amplifier was HBM Quantum MX 840, evaluation software was Catman AP. The sampling rate frequency was 10 Hz. The load – displacement diagrams are illustrated in Figure 2 and the results are summarized in Table 1.

Figure 1 The test arrangement

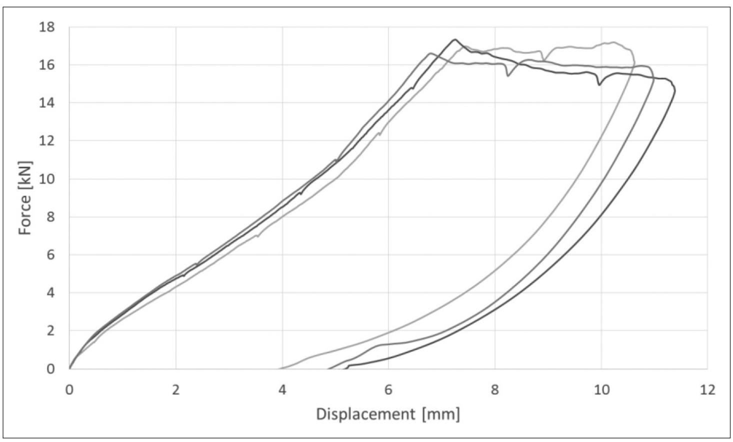

Figure 2 Force-displacement diagram of KS fastening

Table 1 Longitudinal rail restraint and stiffness of rail fastenings (without any vertical load)

Test	Longitudinal rail restraint [kN]	Longitudinal stiffness [kN/m]
1	15.81	2268
2	15.59	2279
3	15.65	2174
Average	15.68	2240

2.2 Longitudinal rail restraint tests with vertical load

The relationship between the longitudinal resistance of the loaded and unloaded track is indicated in Figure 3 according to EN 1991-2:2003 Standard. This standard specifies that the longitudinal resistance of the ballast is three times greater and that of the rail fastenings is twice higher than that in the unloaded condition.

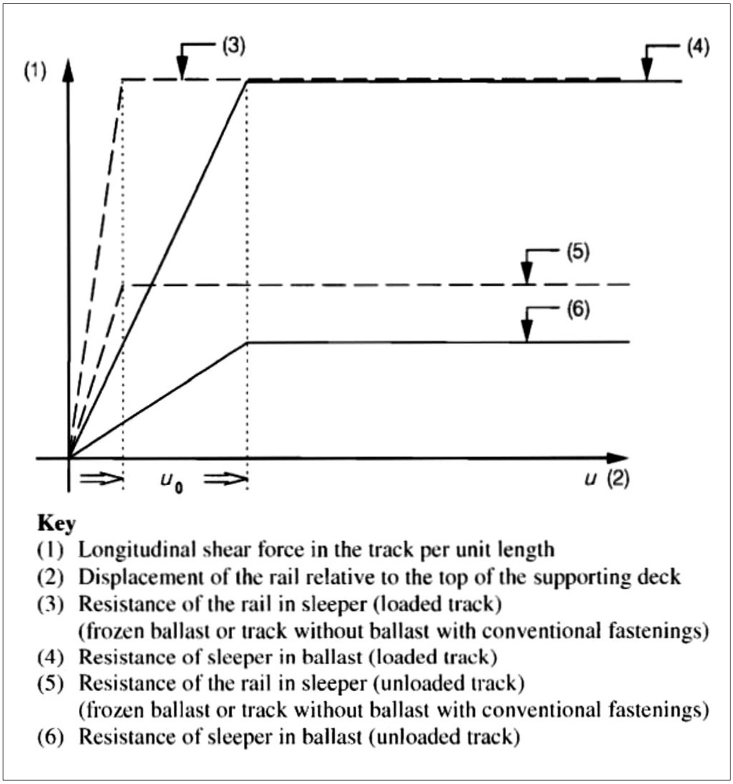

Figure 3 Variation of longitudinal shear force with longitudinal track displacement for one track [2]

The longitudinal rail restraint of the Vossloh Skl12 fastening has been determined as described in Chapter 2.1 in case of the unloaded track. Additional test series were carried out to determine the longitudinal rail restraint of fastenings loaded vertically in function of the vertical load. The tests were carried out in cases the fastening was loaded by 20 kN, 40 kN, 60 kN, 80 kN and 100 kN. The measurement results are illustrated in Figure 5.
In further calculations the longitudinal rail restraint has been taken into consideration that was obtained at a vertical load of 60 kN acting on the rail top. The results are indicated in Figure 6. The test results obtained at a vertical load of 60 kN are indicated in Figure 6, a longitudinal rail restraint of 34,11 kN and a longitudinal stiffness of 4500 kN/m have been obtained. The relationship between the loaded and the unloaded conditions is approximated well by the EN 1991-2:2003 Standard.

Figure 4 The test arrangement (with vertical load)

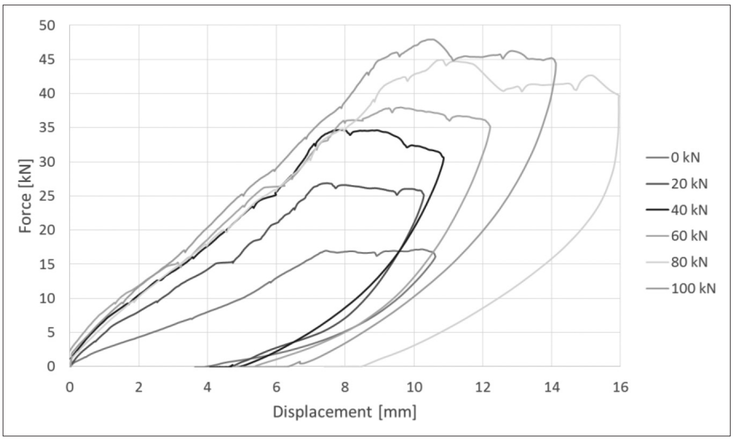

Figure 5 Force-displacement diagram of KS fastening with different vertical loads

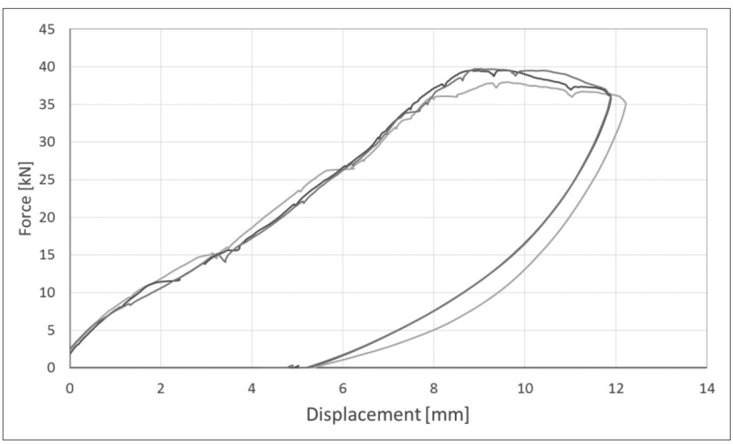

Figure 6 Force-displacement diagram of KS fastening with 60 kN vertical load

3 FEM models

The finite-element software of AxisVM 13 was used for models. The model structures consist of one rail of section 60E1 and half of the cross-sectional area of the bridge [3]. The static model of the bridge is illustrated in Figure 7. The fix support is located at the left hand-side and there are moving supports at mid-span and the right hand end.

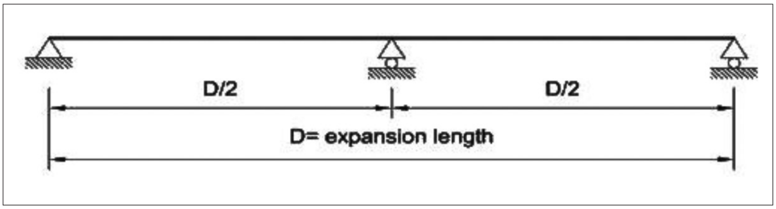

Figure 7 The static model of the railway bridges

It has been assumed in the models that a ballasted track with CWR joins the bridge at its both ends. The longitudinal resistance of newly laid ballast can be 5 N/mm on an unloaded track. The longitudinal ballast resistance of the track increases under the load of train. In case of loaded track the ballast longitudinal resistance is 18 N/mm in our calculations [2]. The properties of the springs between the CWR and the bridge – are defined on the basis of the laboratory tests. European Standard EN 1991-2 [2] require that the braking effect of the trains into the rails be substituted by a longitudinally uniformly distributed load of 20 kN/m per two rails that is 10 kN/m per one rail through a total length of 300 m. It has a maximum value of 6000 kN on the bridge. The acceleration of the trains is to be taken into consideration by an evenly distributed longitudinal load of 33 kN/m with a total value of 1000 kN. Of the two effect, it is the braking that produces higher force, therefore this is critical. In case of critical load combination the position of maximum values of normal forces generated by the change of temperature and by braking should coincide [4] [5] [6].

4 Determination of normal forces

First the maximum values of the normal forces in the bridge structure, the fixed bearing and the continuously welded rail track were determined in case the vertical load of the vehicle is neglected [4]. The results are summarized for tracks with wooden sleepers and Skl12 rail fastenings on bridges with expansion length of 40 m, 70 m and 100 m without any rail expansion joints, Table 2. The FEM models have been built also with the assumption of the track loaded vertically as well. Also bridges with expansion length of 40 m, 70 m and 100 m have been modelled. The results are summarized in Table 3.

Table 2 Maximum normal forces without any vertical load

Expansion length [m]	Maximum normal force [kN]		
	Bridge structure	Fixed bearing	CWR track
40	±1051	±1051	-1701/+1947
70	±1666	±1666	-1731/+1977
100	±2054	±2054	-1855/+2102

Table 3 Maximum normal forces with 60 kN vertical load

Expansion length [m]	Maximum normal force [kN]		
	Bridge structure	Fixed bearing	CWR track
40	±1162	±1120	-1433/+1680
70	±1927	±1893	-1751/+1998
100	±2466	±2428	-1973+/2219

5 Conclusions

It can be concluded from the results that the difference between the normal forces in the loaded track and the unloaded track increases with increasing expansion length. Greater internal forces are resulted on the loaded track. Omitting the vertical load of the vehicle is not an approximation in favour of safety. The proportion between the loaded and the unloaded conditions increases with expansion length, according to our computations the relationship is linear (Figure 8).

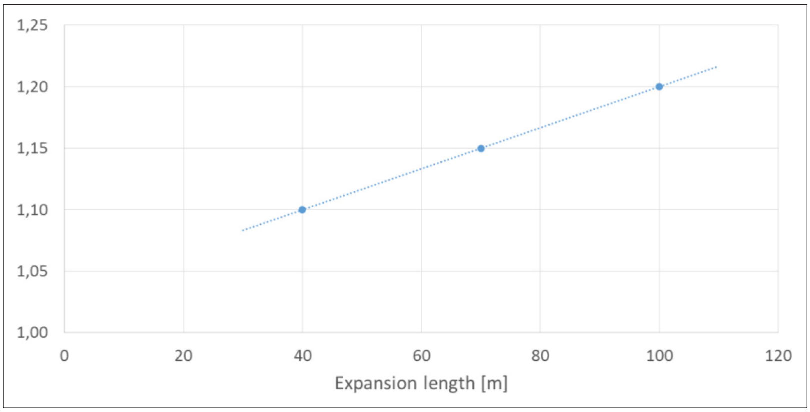

Figure 8 Proportion between internal forces obtained on loaded and unloaded conditions in function of the expansion length of the bridge

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