FINAL REPORT

Numerical modelling of track-box behaviour

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PARTNERS :

- Société Nationale des Chemins de Fer (SNCF)
- Administrador de Infraestructuras Ferroviarias (ADIF)
- Géodynamique et Structure (GDS)
- Centro de Estudios y Experimentacion de Obras Publicas (CEDEX)
- Ecole Centrale de Paris (ECP)
- Linköping University (LU)
- Swedish National Rail Administration - Banverket (BV)

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Final report of ECP research

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1 Numerical modelling of the dynamic behaviour of the track-box

One of the tasks of the SUPERTRACK project concerned the physical modelling of the railway track by using large-scale experiments. It corresponds to laboratory tests in which a real cross-section of ballasted railway track is introduced and studied in a large (full-scale) metallic box, *the track box*. This report deals with the modelling of the track-box and the study of its dynamic response when the system is subjected to vertical loads.

1.1 Description of track-box

The Track-Box is a metallic structure composed of a 20×5×4 m box (see Fig. 31) reinforced with different kinds of beams (IPE240, IPE300, etc). Dimensions in the following figures are given in millimeters.

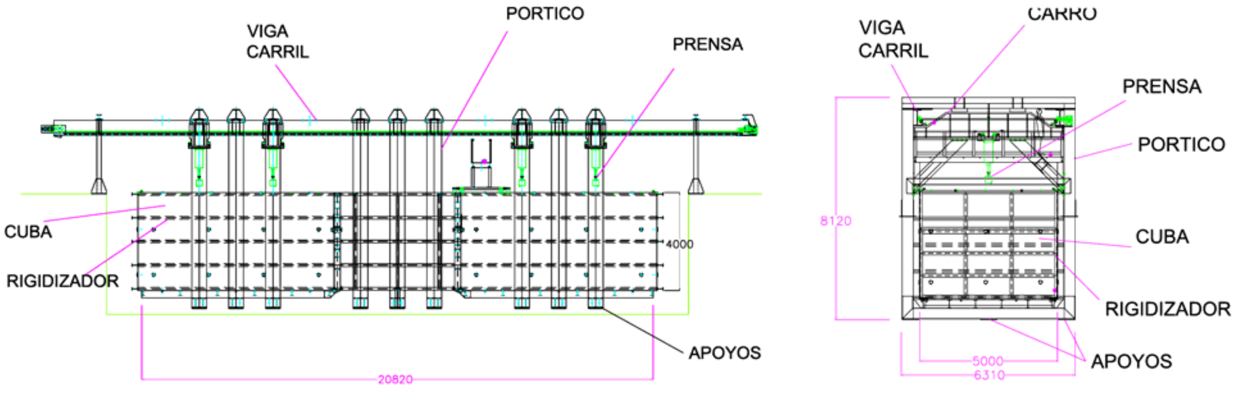


Fig. 31 Plans of the track-box.

During the construction of the track-box, new structural elements were introduced with respect to the initial system (see Fig. 32); this includes four additional contact beams at the bottom of the structure and lateral frames at the top.

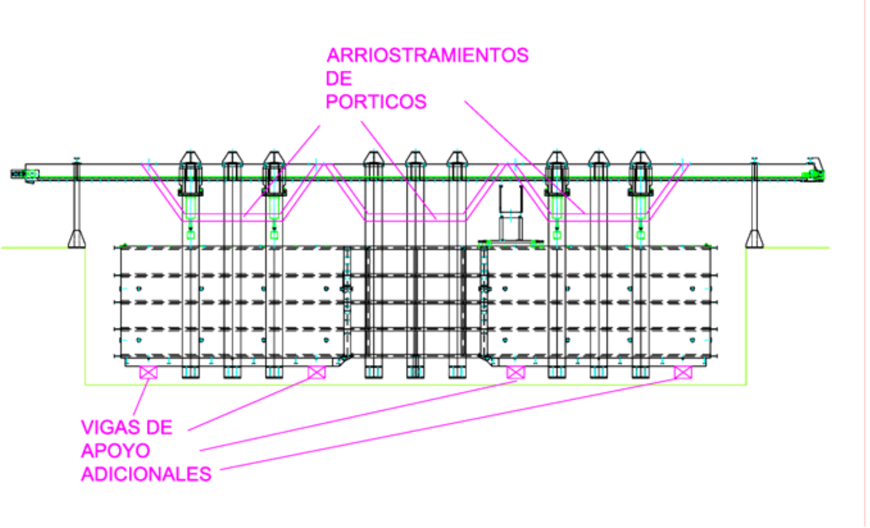


Fig. 32 Modifications added to the initial track-box

1.2 Model of track-box structure

A model of this structure was constructed using the finite element method. The Structural Dynamic Toolbox of *Matlab* was used to get the mesh of the structure and to study the dynamic behaviour of the system.

The first model built represents one of the lateral module of the track-box (see Fig. 33) whose dimensions are 8×5×4 m. It can be seen that the modifications mentioned previously have been taken into account.

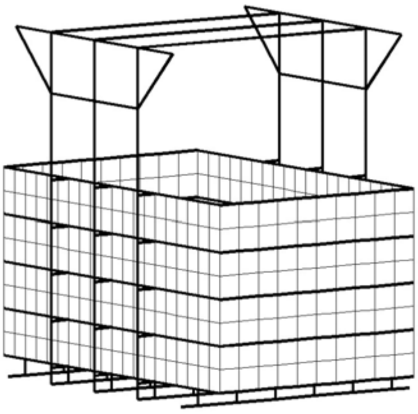
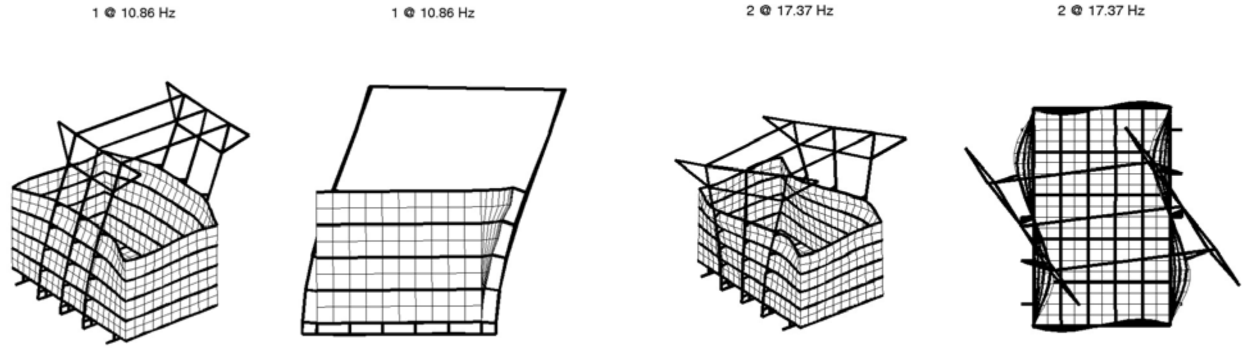


Fig. 33 Model of one part of the track-box

1.3 Study of dynamic behaviour of the structure

With this first model, the eigen-frequencies and the eigenmodes were calculated. In Fig. 34, the modes 1 to 6 are shown since they represent the most significant modes with respect to the structural dynamic response. The eigen-frequencies of the first six elastic modes range from 10.86 Hz to 22.94 Hz.



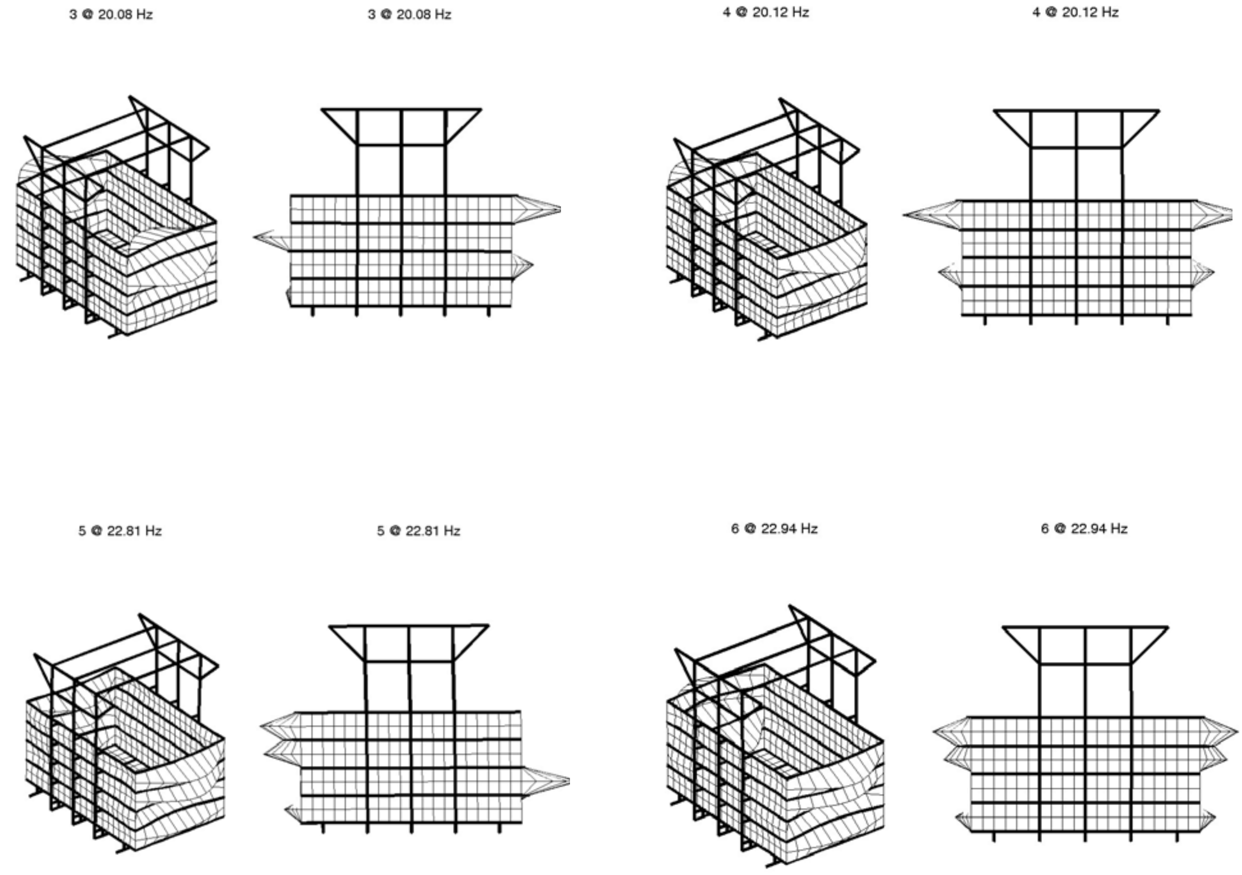


Fig. 34 First elastic modes

The two first modes are related to the frames displacement. The first one corresponds to a bending movement and the second corresponds to a torsional mode. From 20 Hz and above, the modes of the walls of the structure appear.

1.4 Model including soil-track system

1.4.1 Properties of soil-track system

The soil-track characteristics are the same as the Madrid-Zaragoza line (see Fig. 35) on which the CEDEX researchers measured responses due to static and dynamic loadings (see dedicated report).

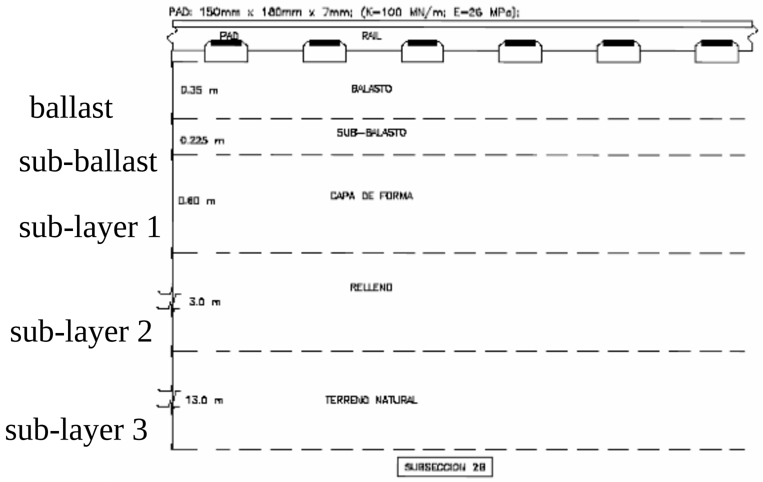


Fig. 35 Soil-track configuration at the Madrid-Zaragoza line

The mechanical properties of the soil are given in Table IV.

TABLE IV: MECHANICAL CHARACTERISTICS OF THE SOIL

	ballast	sub-ballast	sub-layer 1	sub-layer 2	sub-layer 3
E (Mpa)	70	70	60	50	50
P (kN/m^3)	15	-	-	-	20
ν	0.15	0.3	0.3	0.3	0.3

E: Young's modulus, P: specific weight, ν: Poisson's ratio

Concerning the track the following data were used:

Rail	UIC60	**Sleeper**	Mono-block
Inertia	3.055E-05 m^4	Height	0.230 m
Volumetric mass	7800 kg/m^3	Width	0.300 m
Section	7.736E-03 m^2	Length	2.600 m
Young's modulus	210 GPa	Young's modulus	30 Gpa
Poisson's ratio	0.3	Poisson's ratio	0.25
		Volumetric mass	2200 kg/m^3

Pad

Length	0.180 m
Width	0.158 m
Thickness	0.007 m
Vertical stiffness	100 MN/m

1.4.2 Measurement of the vertical deflection in the static and dynamic cases

Figure 36 shows a sketch of the GIF (now ADIF) locomotive used for the tests. It is made of two bogies with three axles. The train load for one axle is equal to 98.5 KN.

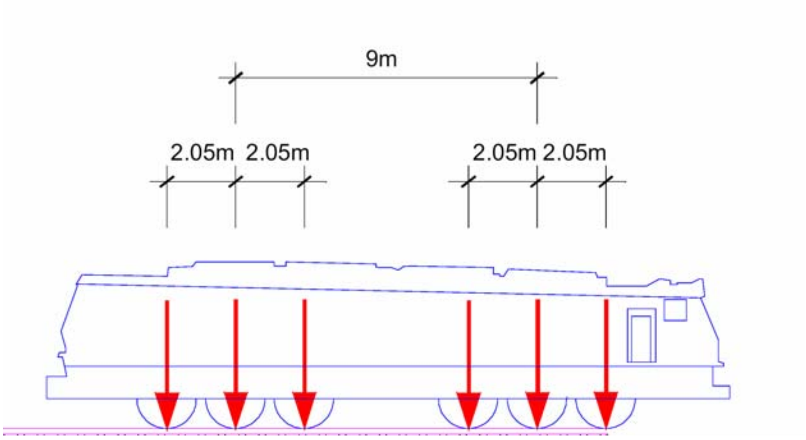


Fig. 36 Locomotive used for the static and dynamic tests

Concerning the in situ measurements, Figure 37 shows the vertical deflection for the static case with respect to the sleeper number.

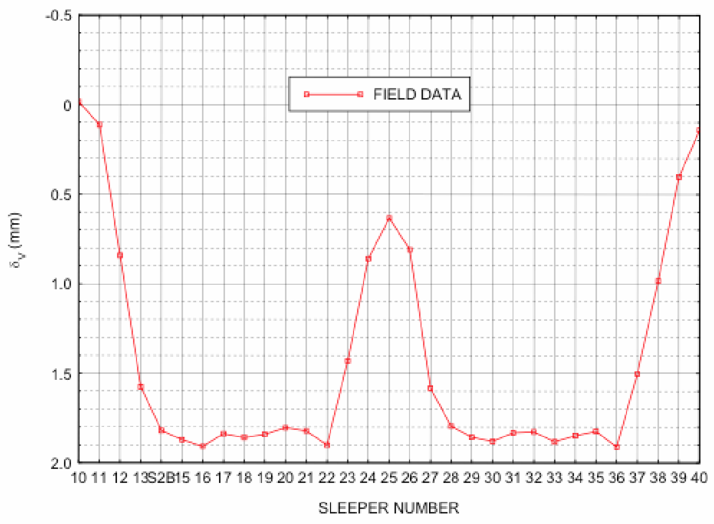


Fig. 37 Static vertical deflection

Moreover, measurements have been done for different locomotive speeds. Figures 38 and 39 present the experimental results for locomotive speeds equal to 40 km/h and 100 km/h, respectively. The graphs show the vertical deflection with respect to time.

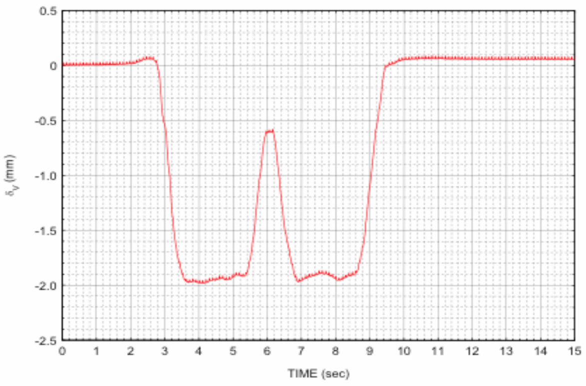


Fig. 38 Vertical deflexion for locomotive speed of 40 km/h

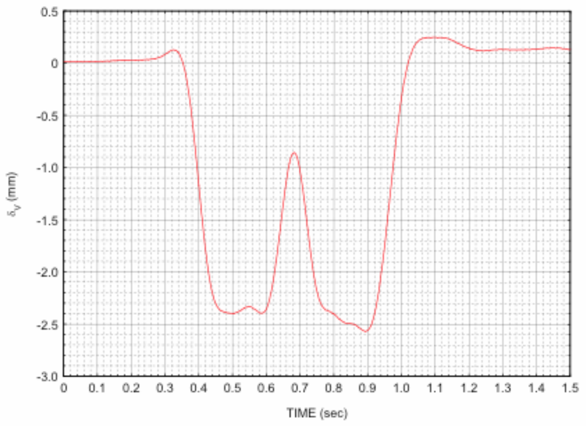


Fig. 39 Vertical deflexion for locomotive speed of 100 km/h

2 Track model

The objective of this paragraph is to construct the model of the track that is introduced in the track-box structure. Using the information given in the preceding sections, a numerical model was constructed as illustrated in Fig. 40.

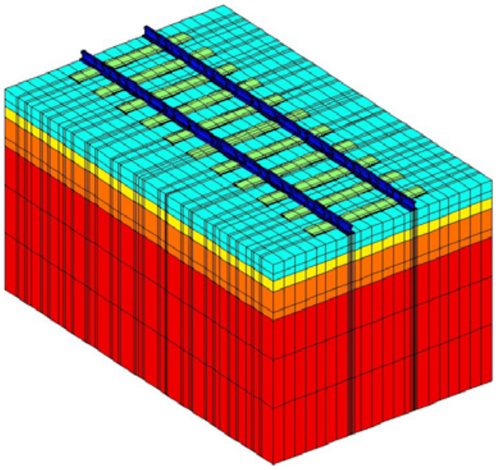


Fig. 40 Model of the track to insert in the track-box structure

The model was validated for the static case. Two track models were considered: one with fixed lateral boundaries which corresponds to a case stiffer than the actual soil, and another one with free lateral boundaries which represents a case softer than the real in situ configuration. Consequently, one should find the measured static deflection between the curves obtained from these two models. Figure 41 compares the static experimental deflection (curve with bullets) and the simulated responses (dashed curve for the model with free lateral boundaries and point-dashed curve for the model with fixed lateral boundaries).

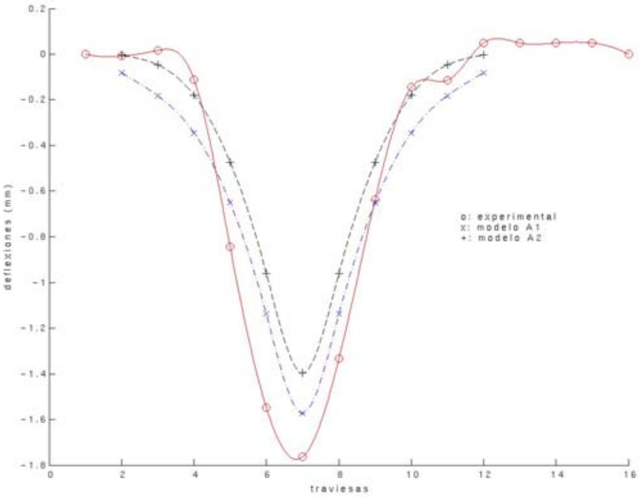


Fig. 41 Comparison between measured and simulated static vertical deflection

It can be seen that the experimental response is not bounded by the simulated responses. The main explanation is that approximated values of Young's modulus for the different layers have been used. So these parameters have to be updated. Nevertheless, one can conclude that the calculated deflections offer a first satisfactory approximation of the in situ static results. Consequently, the dynamic case can be considered and the influence of the track-box structure on the dynamic behaviour of the track can be studied.

3 Influence of track-box structure on dynamic behaviour of track

This chapter aims at studying how the new environment of the track-soil system, that is the metallic structure of the track box, can influence the behaviour of a track section placed inside. So the model constituted of the track-box structure (cf. section 2) and the track model is studied (see Fig. 42).

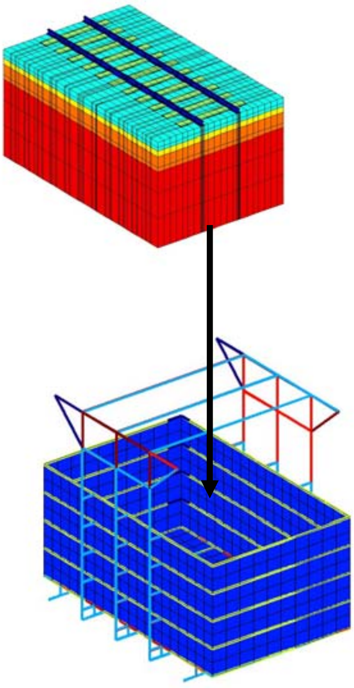


Fig. 42 Model of the track-box structure including the soil-track system

Two models were considered: at first the track model (alone) with fixed lateral boundaries which is considered as the most representative of the behaviour of the actual track (even if the boundary conditions are more rigid than the reality). This model is named model A2. A comparative study was carried out using the model A2 and the model described in Figure 42 (in which the lateral boundaries of the track model are fixed to the walls of the track-box structure). This model is named model B1. Figure 43 shows the transfer functions related to the vertical displacement of a rail point with respect to the frequency for these two models.

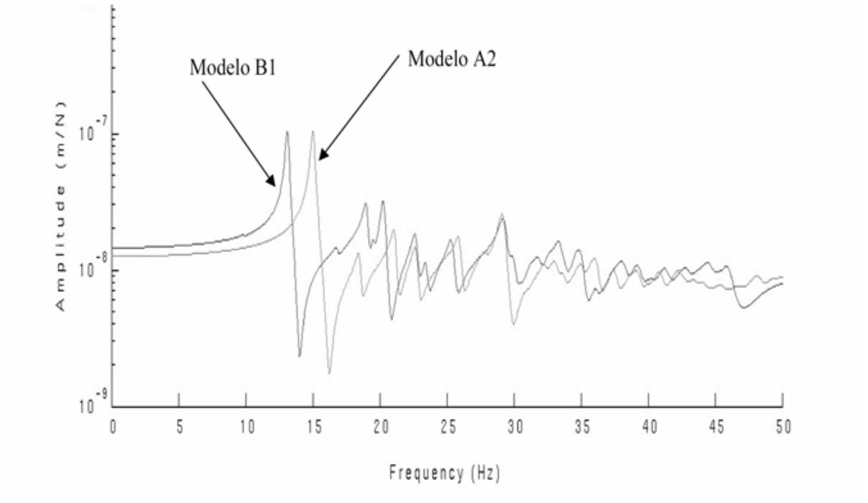


Fig. 43 Transfer functions for models A2 and B1

The responses for the two models are quite the same. In a general point of view, we have observed that the same modes of vibration work for models A2 and B1 but with different eigen-requencies. Then, if the actual behaviour of the track-soil system is not far from the behaviour of the model A2 (same vibration modes but with higher frequencies), we can conclude that the behaviour of the track inside the track-box structure will be qualitatively the same.

<u>Remark:</u> Another study was carried out, related to the influence of the contact conditions between the lateral boundaries of the track model and the walls of the track-box structure. Two models were compared: one for which the displacement of the lateral boundaries are the same for the track and the structure, another one where the horizontal displacement are the same but with independent vertical displacement. It was observed a difference of 8% between the two models for the maximal vertical deflection of a rail point subjected to an axle load of 98.5 K