STATIC AND DYNAMIC TESTS ON RAIL FASTENING SYSTEMS

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Samenvatting

Door het Laboratorium voor Weg- en Spoorwegbouwkunde van de TU Delft werd een serie laboratoriumproeven uitgevoerd op railbevestigingssystemen op betonnen dwarsliggers volgens nieuwe Europese CEN normen. Doel was de bepaling van kenmerkende parameterwaarden onder statische en dynamische belastingscondities. Centraal onderdeel van iedere proefserie was een dynamische proef met 3.10^6 belastingswisselingen. Voor en na deze proef werden een aantal statische proeven uitgevoerd. De resultaten lieten een variatie van resultaten zien afhankelijk van het type bevestiging. Ook slijtage en breuk van sommige componenten werd waargenomen. Gelet op de belangstelling bij producenten/gebruikers heeft dit proefprogramma de mogelijkheid om uit te groeien tot een standaard beproeving waarbij de CEN normen nog wel verder dienen te worden geoptimaliseerd. Een vergelijkbaar proefprogramma zou ook kunnen worden ontwikkeld voor bevestigingssystemen op platenspoor of voor embedded railconstructies.

Summary

The Roads and Railways Research Laboratory of the TU Delft (Delft University of Technology) conducted a series of laboratory tests on of rail fastening systems on concrete sleepers according to new European CEN standards. The aim was to determine typical parameter values under static and dynamic loading. The central part of each test series was a dynamic test with $3 \cdot 10^6$ load cycles. Before and after this test a number of static tests was carried out. The results showed a variety of results depending on the type of fastening used. Wear and cracking of some components were also noted. With a view to the interest of manufacturers/users this test programme may well have the possibility to develop into a standard test, whereby the CEN standards should be further optimised. A comparable test programme could also be developed for fastenings systems on slab track or for embedded rail constructions.

Contents

1. Introduction

As practice shows, the use of concrete sleepers in railway engineering is proliferating at the expense of wooden sleepers. However, an important problem associated with concrete sleepers is the greater susceptibility to dynamic loading due to train loads, which may give cause to the initiation of cracks and fractures in the sleepers, wear and loosening of the fastening components. New fastening designs are proposed to withstand the more severe loading conditions and to improve durability. To assess the suitability of these designs it is of utmost importance to perform repeated loading tests on the sleeper/fastening assembly in a laboratory environment.

More specifically, appropriate tests should be carried out to ascertain if the fastening system models complies with the requirements set for the application of the sleeper/fastening combination in high speed lines or in heavy haul lines.

Within the framework of the introduction of a new European standard (CEN/TC256/SC1/WG17) (referred to as 'Standard' in this paper) for the testing of complete rail fastenings systems on concrete sleepers the Roads and Railways Research Laboratory of the Delft University of Technology (TU Delft) conducted a static and dynamic laboratory test programme on the subject [1]. This paper deals with the loading, measuring and processing techniques, which were applied in the test programme and gives the experiences and further possibilities of this kind of research.

The load excitation in this test series was accomplished using two closed loop electro-hydraulic actuators (MTS Systems), one of 150 kN for the vertical load and one of 50 kN for the horizontal longitudinal load. To measure the relative movement of the rail with respect to the sleeper 6 LVDT's (displacements transducers) with a range of 10 mm were employed.

2. Description of the different tests

Each test combination was subjected to the following test series (the codes refer to the corresponding test description in the Standard. These are specified in the Literature section [2]):

1a. Clamping Force Measurement (EN BBB-7);
2a. Longitudinal Restraint test (EN BBB-1);
3a. Vertical stiffness measurement (EN BBB-4);
4. Repeated loading in inclined rig, for 3 million cycles (EN BBB-4);
3b. Repetition measurement 3.;
2b. Repetition measurement 2.;
1b. Repetition measurement 1.

Of each test a short description will be given.

2.1. Clamping force test

The clamping force, exerted by the fastening system, is of major importance for the transmission of the load to the sleeper. A certain minimal value of the clamping force should always be present. Furthermore, the effect of the upward movement of the rail, causing a vertical tensile load on the fastening anchors, should be taken into account.
To quantify this a quasi-static test was carried out on the combination rail, fastening and sleeper (Figure 1). In this test, the rail is supported while the sleeper is hanging on the fastening. The sleeper is loaded via an auxiliary beam.

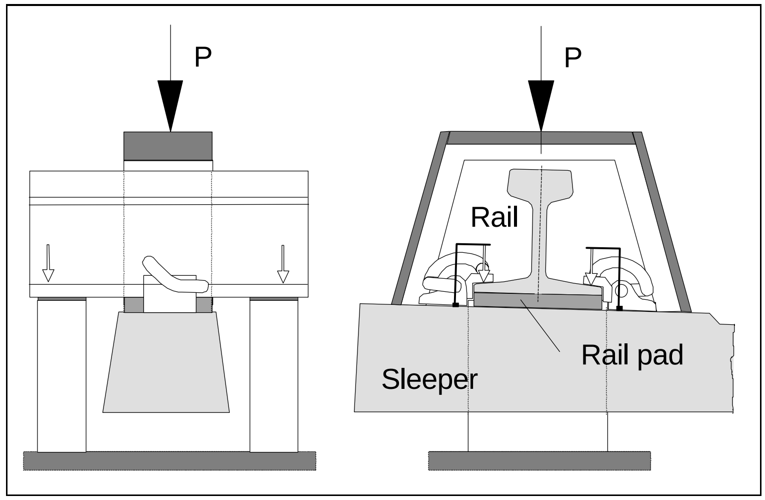

Figure 1. Test arrangement for clamping force measurement

The loading procedure, depicted in Figure 2, is as follows:

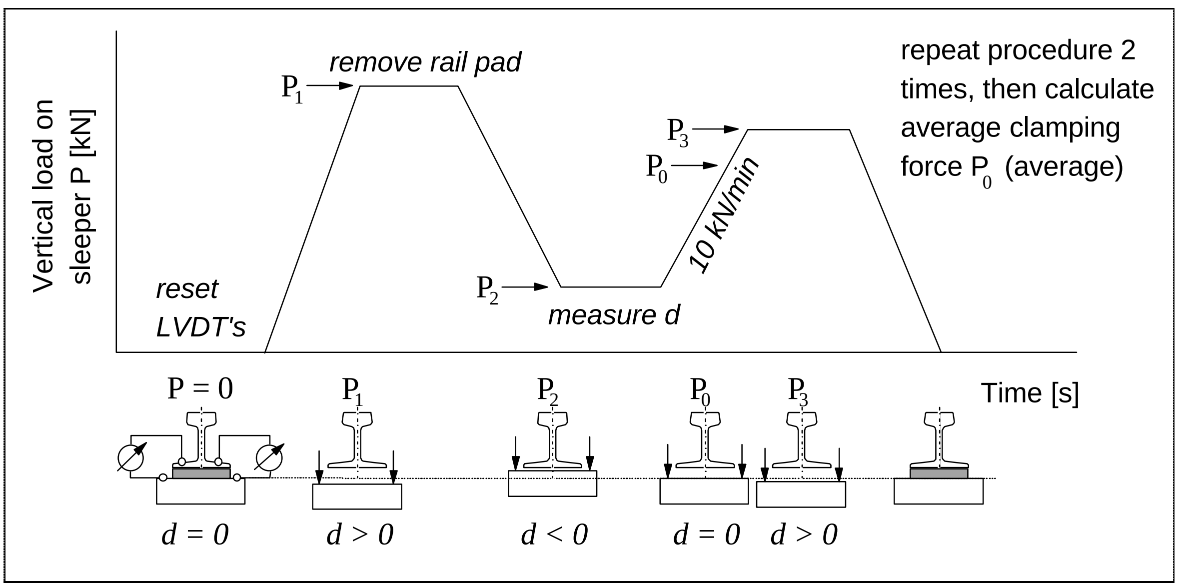

Figure 2. loading procedure for clamping force measurement

P_1: force, at which pad can just be removed;
P_2: force, for which:
- either : $P+mg/1000 \leq 2$ kN (m = mass sleeper+fastening+frame),
- or : sleeper makes contact with the rail;

P_0: force, at which d = 0, to be determined after the test from the load/displacement characteristic;
P_3: $1.1P_0$-mg/1000.

2.2. Longitudinal restraint test

In considerations about creep, relaxation, temperature effects, pull apart of broken rail and braking forces it is useful to know the relation between the longitudinal load on the fastening and the displacement in the longitudinal direction. Especially the maximum load is of importance.
Figure 3 shows the measuring principle. The sleeper is secured by a rail fastening assembly to the supporting structure. The position of the working line has been chosen in such a way as to minimise the bending moment on the fastening.

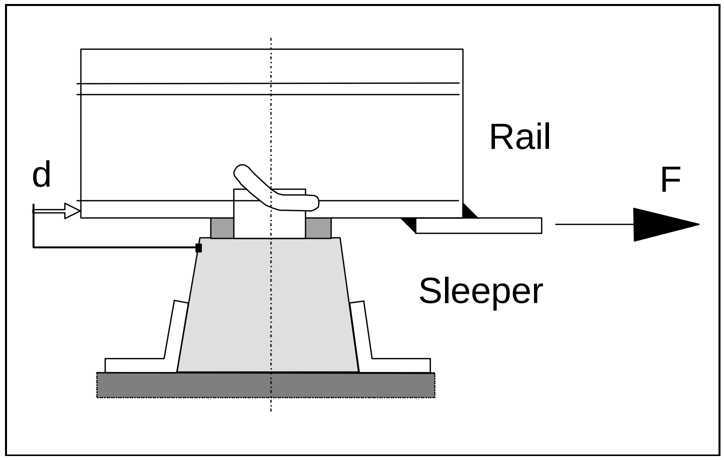

Figure 3. Test arrangement to measure the longitudinal force

The prescribed way of loading is indicated in Figure 4. It concerns a static test without vertical loading. The load step is 2.5 ± 0.3 kN. At some crucial moments (increasing the load, slip through) the measuring signals were recorded at a higher sampling rate.

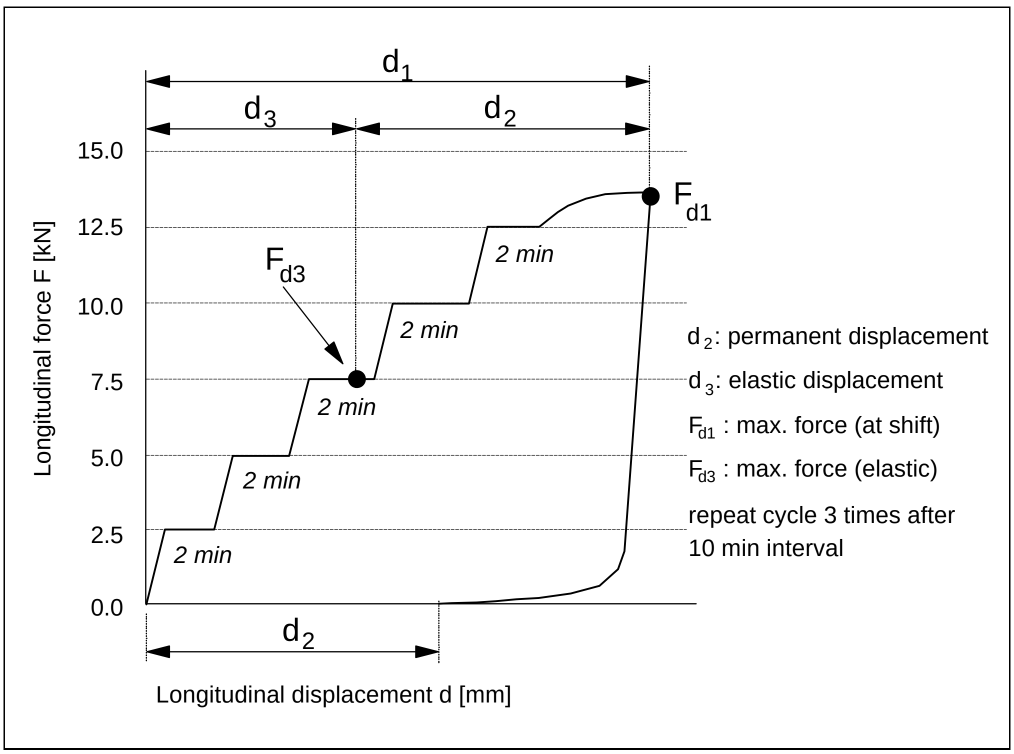

Figure 4. Characteristic of longitudinal load/displacement

A general requirement in the CEN standard concerns the longitudinal restraint, which shall not be lower than 7 kN.

2.3. Vertical stiffness test

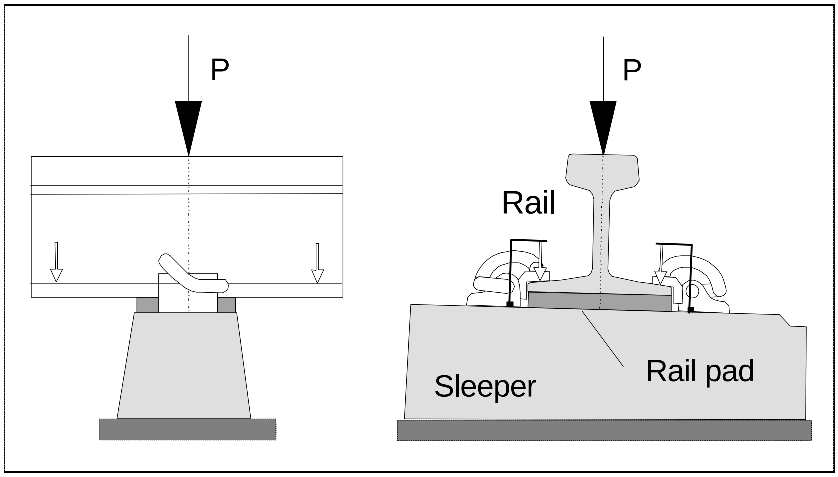

Figure 5. Measurement of vertical stiffness

To determine the static vertical load of the complete fastening the test assembly, supported horizontally, is loaded by a vertical force of 80 ± 1 kN with a rate of 50 ± 5 kN/min (Figure 5). After one minute the load is removed. The loading /unloading cycle is repeated two times. During the third cycle the vertical displacements are measured at the four corners of the rail. From this, the average maximum displacement d [mm] of the rail is calculated. Finally, the vertical stiffness k is determined as the quotient of the load interval between 5 kN and 80 kN and the corresponding mean vertical displacement d [mm]. The unit of k = MN/m (=kN/mm).

2.4. Cyclic loading test

The laboratory test to assess the effect of repeated loading is the means of assessing the potential long-term performance of the fastening in the track. [2]. The cyclic repeated loading is meant as a simulation of the repeated loading of passing trains.
The test assembly, consisting of a short length of rail, fastening system and one (half) sleeper, was fixed in the test rig. The bottom plane of the sleeper acted as reference plane for the force directions.

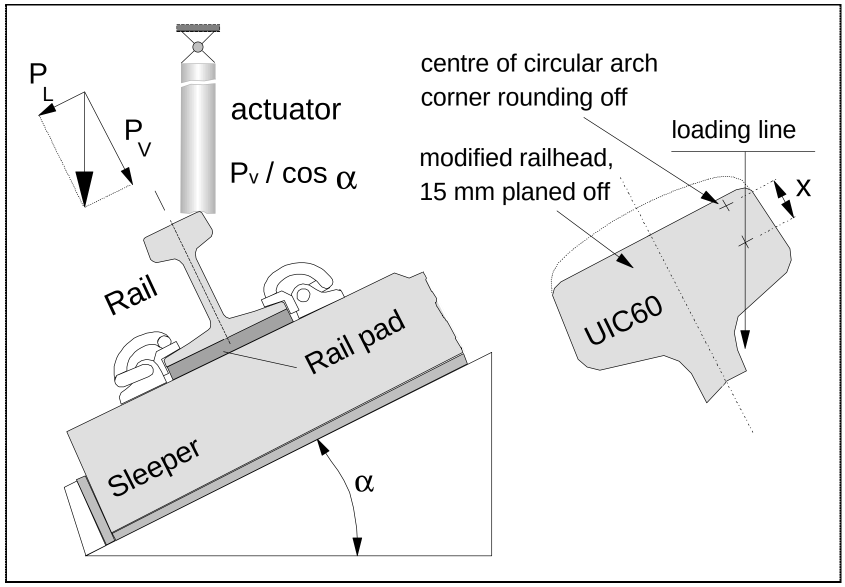

Figure 6. Test arrangement for cyclic repeated loading test

To create two forces simultaneously with one hydraulic actuator, the test specimen is tilted over a certain angle a by inserting a stiff wedge between sleeper and the supporting structure. (Figure 6). In this way two force components are present, one parallel and the other perpendicular to the bottom plane of the sleeper.

A servo-hydraulic actuator applies the constant amplitude cyclic force. The actuator load is introduced on the machined railhead by means of a load application head provided with a concave surface to concentrate the load on the right reference point. The other side of the actuator is connected to a hinge to enable the free movement of the railhead.

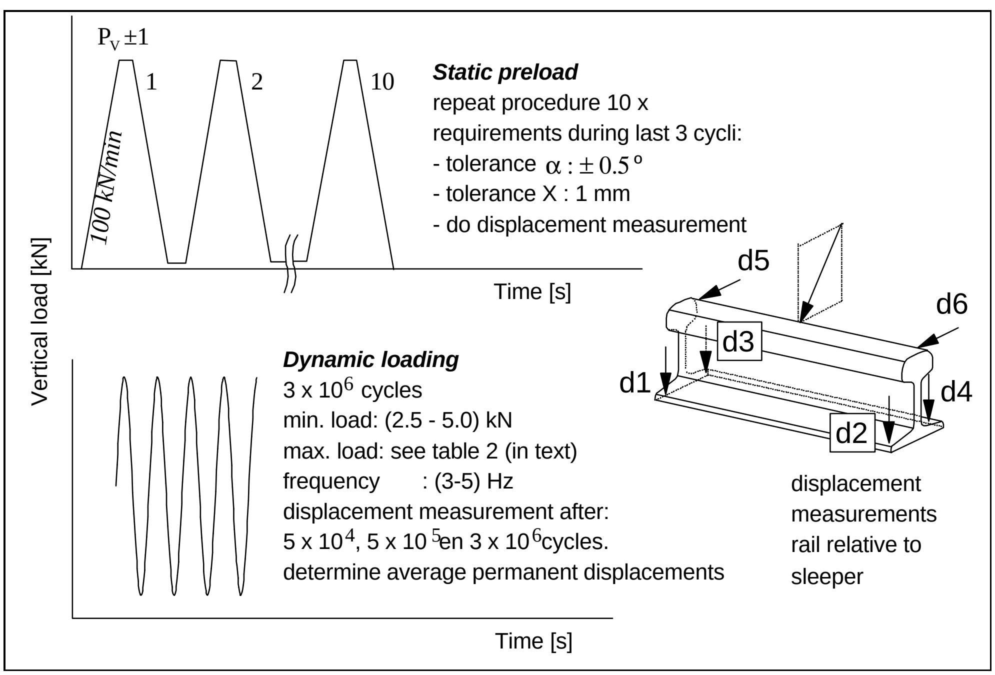

Figure 7. Test procedure for cylic loading testing

The cyclic loading procedure is shown in Figure 7. Before starting the dynamic load the rail is quasi-static preloaded and unloaded 10 times.

In this test six measurements are taken, four vertical at the edges of the railfoot and two horizontal at the railhead, parallel to the railfoot.
The cyclic loading test itself takes about two weeks in case of continuous operation.

To present the information of the mean residual displacement more clearly, the data containing the residual displacements of the rail after 3.10^6 cycles can be presented according to the transformation scheme next to Figure 8.

Referring to the location of the displacement transducers (Figure 7) the following relations hold for the three degrees of freedom of the rail movement (rail assumed not deformable):

Vertical displacement rail:

$w = ¼ (d_1 + d_2 + d_3 + d_4)$;

Lateral rotation rail:

$\tan\varphi = ½ (d_1 + d_2 – d_3 – d_4) / b$;

Lateral displacement railhead:

$v_{head} = ½ (d_5 + d_6)$;

Lateral displacement railfoot:

$v_{foot} = ½ (d_5 + d_6) - h \tan\varphi$.

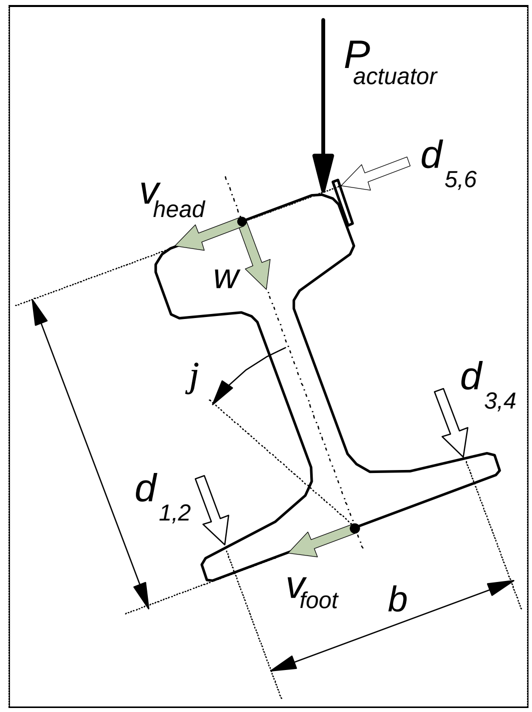

Figure 8. Transformation of displacements

3. Final visual inspection

After completing all tests on the test assembly concerned the fastening assembly should be dismantled to enable the visual inspection of all track components, including the rail pad.

4. Results

All results are collected in the form of Test Reports, as prescribed by the CEN Standard, with detailed information for each test assembly and for each sub-test. The Test Report will be forwarded to the principal of the test project.

5. Conclusions

1. The results of a test programme on representative track systems showed some variety in the data depending of the assembly type. The value of the longitudinal rail restraint appears to be strongly dependent on the tolerances of the components.

2. No failures with regard to the rail, the sleeper or the fastening anchorage could be detected in the final inspection. The wear of the rail pad can vary considerably. If an insulator is applied between rail clip and railfoot, there is a risk that it may not survive cyclic loading test.

3. The CEN standards were rather satisfying to work with. However, some improvements could be introduced regarding definitions and experimental techniques.

4. Manufacturers and users have shown an interest in this kind of testing. It is anticipated that in future a full test programme, as specified by the CEN Standards [2], should be considered. Hence, to complete the test programme, the following tests should me added to the tests already mentioned:

   - Measurement of rotational restraint (around vertical axis) (EN BBB-2);
   - Determination of the dynamic damping (EN BBB-3);
   - Determination of the electric resistance (EN BBB-5);
   - Effect of exposure to severe environmental conditions (EN BBB-6);

5. The only test not specified here is number 9, In situ tests (EN BBB-8), because they are not laboratory related.

6. Moreover the test programme methodology for the testing of fastenings on concrete sleepers could also be extended to other forms of rail fixturing techniques, such as fastening on slab track, embedded rail constructions with classical rail sections or special rail sections for 'silent track' designs.

6. Literature

[1] Zand, J. van 't and Moraal, J., Static and dynamic tests on rail fastening systems. Report 7-97-118-2, Roads and Railways Research Laboratory, TU Delft, September 1997.

[2] Final working draft of WG 17. CEN/TC256/SC1/WG17. Railway Applications – Track Fastening systems: Draft EN AAA, June 1996 and Draft EN BBB, December 1995.