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Železniške naprave - Infrastruktura - Določitev laboratorijskih preskusnih parametrov za ocenjevanje mehanske vzdržljivosti sistemov za pritrjevanje tirnic - Komplementarni element

Railway applications - Infrastructure - Determination of laboratory test parameters for assessing the mechanical durability of rail fastening systems - Complementary element

Bahnanwendungen - Infrastruktur - Bestimmung von Laborprüfparametern zur Beurteilung der mechanischen Dauerhaftigkeit von Schienenbefestigungssystemen

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English Version

Railway applications - Infrastructure - Determination of laboratory test parameters for assessing the mechanical durability of rail fastening systems - Complementary element

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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European foreword

This document (FprCEN/TR 17320:2018) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This document is currently submitted to the Vote.

1 Scope

This document presents the technical basis for the loading conditions (the load magnitude, the load angle and the position of load application) to be used when performing the repeated load tests described by EN 13146-4. This basis consists of measurements made in-track, theoretical analysis and experience of using the previous versions of the EN 13481 series of standards. Statistical variations in the applied loads and their influence on safety factors are also considered.

2 Purpose

This document has been prepared to provide a reference document that will inform future revisions of the EN 13481 series of standards and other standards that define Performance Requirements for rail fastening systems. Specifically, it provides a basis for calculating the loads that should be applied in the repeated load tests that are performed in laboratories in order to confirm the durability of rail fastening systems according to the method given by EN 13146-4.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13481-1:2012 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

• IEC Electropedia: available at http://www.electropedia.org/

• ISO Online browsing platform: available at http://www.iso.org/obp

3.1
rail seat
single discrete rail fastening point e.g. a sleeper end or location of a single baseplate

4 Symbols and abbreviations

E	Young's Modulus of the rail steel
F	vertical component of load at a single rail seat
F_{max}	load carried by the rail seat directly below the wheel
I	second moment of area of the rail for vertical bending
k	stiffness of the (“Winkler”) foundation
V	maximum train speed [km/hr]
W	vertical wheel load
a	sleeper or support spacing

5 History and background

5.1 ERRI D170 Reports; Evolution of EN 13481

Committee D170 of the European Rail Research Institute (ERRI, formerly ORE) undertook the first work toward the development of a European standard for testing rail fastenings (and concrete sleepers) between 1986 and 1994. This committee evaluated the test methods used by several major European railways in order to establish “best practice”. The results of this work were published in a series of five technical reports [1 – 5].

In 1992, the European Standards organization, CEN, established a new Technical Committee, TC 256, to develop standards for Railway applications. These standards were necessary in order to support the introduction of EC Utilities Directive 93/38/EEC. This directive made it mandatory to use European Specifications (including European Standards) as the technical basis of procurement for major public utilities organisations, including railways (whether publicly or privately owned). The part of Technical Committee TC 256 that was formed to develop European Standards for rail fastenings was Working Group 17 (WG 17), which is part of Sub-Committee SC 1 “Infrastructure” of CEN/TC 256. This working group included several experts who were also serving on ERRI Committee D170, so the work of the ERRI committee was absorbed into the work of WG 17 from the outset.

NOTE The Utilities Directive has been progressively updated. The latest version of the Utilities / Procurement Directive is 2004/17/EC.

The ERRI D170 reports [1-5] consider the case of conventional mainline track: concrete sleepers in ballast, 60 kg/m rail and a maximum axle load of 22,5 t. Some reference was also made in these reports to experience on the new high speed operations in France. In order to account for the conditions found on other types of track, such as ballastless track (see 5.8), it was necessary to extrapolate from the empirical data available for conventional mainline and high speed track [1-5].

The use of a reduced height of rail section in repeated load tests performed in the laboratory was introduced in ERRI D170 Report 5 and it is explained by a paper published in the International Heavy Haul Conference in 1989 [6]. A section of rail that has reduced height is used for the test so that the over-turning moment on the rail is reduced, without reducing either the vertical or lateral components of the load applied to the rail. It is appropriate to do this because the test is normally performed for a short piece of rail that is fastened to the support at only a single rail seat. This means that in the laboratory test, a single fastening system shall provide all of the resistance to the over-turning moment applied by the actuator to the rail. In track, a long rail is fastened to the support at numerous rail seats and numerous fastening systems along the length of the rail provide resistance to the applied over-turning moment.

In the current standards, the modified rail height is defined in terms of a distance measured downward from the gauge corner. It is accepted that, for future standards development, defining a distance measured from a different reference point or plane could make the method applicable to a wider range of rail sections.

The original EN 13481 series of standards, published in 2002, distinguished between two basic 'categories' of fastening systems – those suitable for “Main Line” application and those suitable for “Light Rail” application. The “Main Line” category was further subdivided into fastening systems with “soft” rail pads and those with “hard” rail pads. Maximum axle load and minimum curve radius assumptions were made for each category. For the “Main Line” case the minimum curve radius was assumed to be 150 m with hard pads and 400 m with soft pads. This led to a requirement to test assemblies with hard pads for a load inclined at angle of 33° and those with soft pads at an angle of 26°.

The standard was extended to include heavy haul applications, by extrapolating from the empirical data available for mainline tracks using methods published at an International Heavy Haul Conference [7]. This extension to the standard was published as a new part standard, EN 13481-8:2009.

The EN13481 series of standards was revised and re-issued in 2012. The most important change was in the definition of fastening 'categories'. The "Light Rail" category was renamed "Category A", with no technical changes. A new category, "Category B", was introduced to cover applications on heavy metro systems and on secondary lines with lighter axle loads, but tighter curves, than the "Main Line" case. The case of mainline track with soft pads and also curves with a radius of less than 400 m (but greater than 150 m) was described by "Category C". This represented a departure from the approach taken to the standards published prior to 2012, where it had been assumed that soft pads would not be used on tight curves. The angle of the inclined load was increased from 26° to 33° to account for this. The case of mainline track with a minimum curve radius of 400 m was described by "Category D". The "Heavy Haul' category became "Category E".

The various fastening categories may be described in terms of a minimum curve radius and a maximum axle load. These are summarized in Table 1 below.

Table 1 — Minimum curve radius and maximum axle load for Categories A to E

Category	**Minimum Curve Radius** m	**Maximum axle load** **kN**
A	40	130
B	80	180
C	150	260
D	400	260
E	150	350

These are the extreme values beyond which the EN 13481 series of standards is not applicable. The definitions in EN 13481-1:2012 give "typical" values of curve radius and axle load which are less severe than these limiting values. Train speed is not a factor in selecting the relevant category.

5.2 System testing v. component testing

CEN/TC 256/SC 1 adopted a policy of writing standards to be used for the type approval of systems and sub-systems within the track structure, rather than standards to be used for the approval of individual components. This is in accordance with the requirements of the EC Utilities Directive 93/38/EEC. All standards developed by WG 17 to date have followed this philosophy.

UIC or individual railway administrations were left to control standards for components of the fastening system.

5.3 Design v. actual loads

To meet the requirements of the EC Utilities Directive and later the EC Interoperability Directives, it shall be possible to demonstrate that a rail fastening system complies with the standard before the details of a particular application are known. This allows a fastening system to be "placed on the market" with a Declaration of Conformity. It is therefore necessary to assess the compliance of the fastening system against a hypothetical or "design" loading case, rather than an estimate made for the loading case appropriate for a particular application.

5.4 Selection of the appropriate hypothetical load case

5.4.1 General principles

The empirical data collected by Committee D170 of ERRI indicates that the most severe loading experienced by rail fastenings in normal use is found on the low rail, for the case of a train travelling slowly around a tight curve (i.e. a condition of severe cant excess).

This same empirical data also indicates that the durability of conventional rail fastening systems is determined by its ability to withstand repeated application of a lateral force to the head of the rail, rather than its ability to withstand repeated vertical forces.

5.4.2 Effect of rail inclination

An increase in the rail inclination, from 1:40 to a 1:20 for example, makes the repeated load test less severe. It can therefore be assumed that a fastening system that has been tested successful at one inclination does not need to be tested again for a case in which the rail inclination is greater. For example, a fastening system that passes a given test at an inclination of 1:40 can be assumed to pass the test at an inclination of 1:20.

5.4.3 Sleeper type

The 2012 (and earlier) standard states that testing shall be carried out on the “type” of sleeper which will be used in the track. This was intended to mean that if a pre-stressed monobloc sleeper will be used with the fastening system under consideration in the track then the test should be performed on a pre-stressed monobloc sleeper (or part of such a sleeper). For the repeated load test, the detailed differences between specific designs of pre-stressed monobloc sleepers for example do not normally have a significant effect. This may not be the case for some of the other tests, such as the electrical test or insert pull-out resistance test. A basic engineering assessment may be used to decide whether or not it is not necessary to repeat tests if the fastening has been shown to comply with standards when tested on a different sleeper. Some laboratories carry out repeated load tests on fastenings on reinforced concrete blocks on the basis that this is another “worst case” condition. If the fastening complies with the standard on such a block, it can be assumed that it will pass the test when it is run on a real sleeper.

5.5 Safety and dynamic factors

Standards developed by WG 17 to date have not explicitly separated the concepts of “Safety factors” from “Dynamic factors”. It is possible to infer factors from the vertical components of the test loads in the standard using a simple (e.g. Beam on Elastic Foundation – see Clause 8 of this report) model with the given axle loads, sleeper spacings and speeds combined with a typical foundation stiffness. Doing this suggests that there is a “Safety plus Dynamic” factor implicit in the vertical component which is approximately $(1{,}2 + 0{,}004 \cdot V)$ where V is the maximum train speed in km/h. This was based on train speeds not exceeding about 200 km/h.

This approach gives results which are consistent with the empirical load cases identified in the ERRI D170 reports.

5.6 Duration of test (3 million cycles) and loading frequency

Historically, repeated load tests were run for 3 to 5 million cycles because this is sufficient to detect fatigue failures in most low alloy steels which have a clear fatigue limit. More recently, it has been found that this number of cycles is also sufficient to indicate durability problems even in non-metallic components.

The loading frequency in the repeated load test, (4 ± 1) Hz, was chosen so that the duration of the test was within practical limits and also so that non-metallic components did not overheat during the test.

5.7 Pass/fail criteria

As discussed in 5.6, for steel components, 3 million load cycles was considered to be sufficient to cause fatigue failure if the local stresses are too high. However, the durability of fastening systems is usually determined by the deterioration of non-metallic components, which may, in turn, cause an increase in the cyclic stresses in the metallic components. The standards developed by WG 17 include a requirement to measure other critical parameters which are dependent on the performance of the non-metallic components. These parameters are the vertical stiffness, longitudinal restraint and clamping force. The change in these characteristics over the course of the repeated load test shall be within set limits. These limits are based on empirical data relating to changes in those parameters in fastening systems known to have unacceptable durability in service and on a need to complete the test in a reasonable period of time.

5.8 Ballasted v. ballastless track

In the absence of any other data, WG 17 standards published to date have used a factor to increase the magnitude of the applied load in the case of ballastless track. This is based on the assumption that for ballasted track the low frequency dynamic stiffness of the ballast and formation is 50 MN/m per sleeper end. For ballastless track, the support was assumed to be rigid. A beam-on-elastic foundation (BOEF) model (8.1) was used to calculate the change in the load on a fastening system due to this difference in the stiffness of the support for ballasted and ballastless track.

A recent review of track stiffness measurements made on ballasted track in the UK [8] shows that the dynamic stiffness (per sleeper end) of the ballast and the formation is in the range from 10 MN/m to 50 MN/m on well-performing track. These measurements were made under-traffic, such that the stiffness values found from them is appropriate to loading at the wheel passing frequency

The lateral load distribution along the length of the track depends on both the stiffness of the lateral restraint (measured at the rail foot, for pure lateral translation of the rail) and also the stiffness of the torsional restraint. For ballasted track, the ballast also has some influence on these parameters.

6 Assumptions about track construction and maintenance conditions

All of the tests which are recommended in the standards are based on an assumption that track is built and maintained to a good standard. That does not mean that there is an assumption of perfection, which would reduce many of the required dynamic and other factors to unity, but it does imply that rail fastening systems which comply with the standards may, nevertheless, fail prematurely if the track condition is very poor. Examples of track conditions which are known to necessitate early replacement of rail fastening components include:

— Rail joints and welds which are “dipped” or misaligned;

— Track with sudden changes in support stiffness (e.g. ends of bridges, transitions between ballasted and ballastless tracks, etc.);

— Ballastless track with inconsistent lateral positioning of fastenings;

— Badly corrugated rail.

In such cases, track maintenance should be carried out to remove the root cause of the track defects, rather than changing the performance requirements of the fastening system.