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Railway applications — Track — Concrete sleepers and bearers with under sleeper pads

National foreword

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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European foreword

This document (EN 16730:2016) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2016, and conflicting national standards shall be withdrawn at the latest by December 2016.

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Introduction

This European Standard relates to the EN 13230 series when the sleepers or bearers are manufactured with Under Sleeper Pad (USP). The USP is an elastic layer fixed to the bottom surface of the sleepers or bearers. This standard applies to the system constituted of the concrete sleepers or bearers and the Under Sleeper Pad.

1 Scope

This European Standard is applicable to concrete sleepers or bearers with Under Sleeper Pads (USP) physically bonded to concrete used in ballast track and define the test procedures and their evaluation criteria. This standard provides particular information in the following areas:

— test methods, test arrangements and evaluation criteria of Under Sleeper Pads;

— test methods, test arrangements and evaluation criteria of concrete sleepers and bearers with Under Sleeper Pads;

— data supplied by the purchaser and by the supplier;

— definition of general process of design approval tests;

— definition of routine tests.

This standard defines the specific test procedures for design approval tests, routine tests and tests concerning the determination of relevant properties of Under Sleeper Pad with or without concrete sleepers and bearers:

— fatigue tests;

— tests of capability for stacked stocking of concrete sleepers or bearers fitted with USP;

— pull-out test;

— severe environmental condition test.

This standard also sets out procedures for testing fitness for purpose and provides information on quality monitoring as part of quality assurance procedures. This standard does not, however, contain requirements pertaining to the properties of Under Sleeper Pads. It is the responsibility of the purchaser to define these requirements

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 206, *Concrete - Specification, performance, production and conformity*

EN 1542, *Products and systems for the protection and repair of concrete structures - Test methods - Measurement of bond strength by pull-off*

EN 10027 (all parts), *Designation systems for steels*

EN 13230-1:2016, *Railway applications - Track - Concrete sleepers and bearers - Part 1: General requirements*

EN 13230-2:2016, *Railway applications - Track - Concrete sleepers and bearers - Part 2: Prestressed monoblock sleepers*

EN 13230-3:2016, *Railway applications - Track - Concrete sleepers and bearers - Part 3: Twin-block reinforced sleepers*

EN 13230-4:2016, *Railway applications - Track - Concrete sleepers and bearers - Part 4: Prestressed bearers for switches and crossings*

EN 13230-5, *Railway applications - Track - Concrete sleepers and bearers - Part 5: Special elements*

EN 13450, *Aggregates for railway ballast*

EN ISO 527 (all parts), *Plastics — Determination of tensile properties (ISO 527, all parts)*

EN ISO 7500-1, *Metallic materials - Calibration and verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Calibration and verification of the force-measuring system (ISO 7500-1)*

EN ISO 9513:2012, *Metallic materials - Calibration of extensometer systems used in uniaxial testing (ISO 9513:2012)*

EN ISO 22768 (all parts), *Permissible machining variations in dimensions without tolerance indication (ISO 2768, all parts)*

ISO 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
track category TC1
track using concrete sleepers or bearers with under sleeper pads designed for urban light rail and some industrial track with a typical axle load between 100 kN and 130 kN, a typical maximum speed of 100 km/h, a typical rail section of 49E1 (as defined in EN 13674-1) and a typical sleeper or support spacing of 650 mm (maximum 750 mm)

3.2
track category TC2
track using concrete sleepers or bearers with under sleeper pads designed for urban light rail and some industrial track with a typical axle load of 160 kN, a typical maximum speed of 140 km/h, a typical rail section of 54E1 (as defined in EN 13674-1) and a typical sleeper or support spacing of 650 mm

3.3
track category TC3
track using concrete sleepers or bearers with under sleeper pads designed for either:

— conventional main line railways with a typical axle load of 225 kN, a typical maximum speed of 200 km/h, a typical rail section of 60E1 (as defined in EN 13674-1) and a typical sleeper or support spacing of 600 mm; or

— track using concrete sleepers or bearers with under sleeper pads designed for lines with large radius curves, often used for high speed trains and having a typical axle load of 200 kN, a typical maximum speed of 320 km/h, a typical rail section of 60E1 (as defined in EN 13674-1), a typical sleeper or support spacing of 600 mm

3.4
track category TC4
track using concrete sleepers or bearers with under sleeper pads designed for mixed traffic line carrying heavy freight trains with a typical axle load of 300 kN, a typical maximum speed of 200 km/h, a typical rail section of 60E1 (as defined in EN 13674-1) and a typical sleeper or support spacing of 600 mm

3.5
ballasted track
track in which the sleepers or bearers are embedded in the ballast

3.6
sleeper
transverse components of the track which control the gauge and transmit loads from the rail to the ballast or other sleeper support

3.7
bearer
transverse components of switches and crossings which control the relative geometry of two or more stretches of running rails and different pieces of special track work, and transmit loads from the rails to the ballast or other sleeper support

3.8
Under Sleeper Pad
USP
elastic layer fixed to the bottom surface of the sleepers or bearers including technologies of bonding between sleepers or bearers and under sleeper pad

3.9
stiffness
force per unit deflection measured under a uniaxial force

3.10
bedding modulus
pressure (force per surface) per unit deflection and measured under a uniaxial load

3.11
stiffness or bedding modulus
stiffness or bedding modulus in vertical direction measured normal to the base of the sleeper where the support is a slab, between two specified applied loads

3.12
static stiffness or bedding modulus
force or pressure per unit deflection measured under a uniaxial static load

3.13
dynamic stiffness or bedding modulus
force or pressure per unit deflection measured under a cyclic uniaxial load

Note 1 to entry: Low frequency dynamic stiffness or bedding modulus: stiffness or bedding modulus measured within the frequency range (2 to 30) Hz (without preloading between defined pressures, see Figure 1).

Note 2 to entry: Higher frequency dynamic stiffness or bedding modulus: stiffness or bedding modulus measured within the frequency range (20 to 450) Hz (under preloading conditions see Table H.1, see Figure 1).

3.14
vibration mitigation
reduction in emission of mechanical vibration and/or structure-borne noise into the surroundings

3.15
geometric ballast plate
GBP
rigid steel plate with a geometrically structured surface simulating ballast contact

Note 1 to entry: See Annex A.

3.16
design approval test
homologation procedure with description of the product properties and test results

3.17
routine test
quality control test in terms of regular manufacturing

3.18
purchaser
operator or user of the equipment, or the customer of the material on the user's behalf

3.19
supplier
body responsible for the use of the EN in response to the purchaser's requirement and also for requirements which apply to the producer or manufacturer

Note 1 to entry: Generally the supplier is the manufacturer of the concrete sleepers and has a sub-contractor for the USPs.

3.20
USP on concrete block
USP bonded on concrete block

Note 1 to entry: See Annex B.

4 Symbols

Table 1 — Symbols

Symbols	Characterization	Units
A	area	mm²
a	acceleration in measurement of higher frequency bedding modulus	m/s²
C	bedding modulus	N/mm³
d	displacement	mm
Δ	variation	-
F	force	N
f	frequency in measurement	Hz
k	stiffness	N/mm
L_H	vibration level related to reference value of 5×10^{-8} m/s	dB
m	mass	kg
N	number of cycles	-
η	loss factor	-
p	pressure	N/mm²
κ	stiffening coefficient between low frequency dynamic bedding modulus and static bedding modulus	-
σ	stress (pressure or tensile)	N/mm²
ω	angular frequency = $2\pi \cdot f$ (for higher frequency bedding modulus)	s^{-1}

Table 2 — Indice of the symbols

Indices	Characterization
0	for frequency, definition of natural frequency
5 Hz, 10 Hz, 20 Hz, 30 Hz	value of frequency in measurement
af	after
av	average
be	before
dyn	low frequency dynamic
H	higher frequency
max	maximum
min	minimum
number	sequential number in order to differentiate types of measurements
pre	preload
stat	static
tend	tendency
test	test load

5 Design approval tests and routine tests

5.1 General

This clause defines the objectives of tests or of required information about the system (sleeper with USP), USP and concrete sleepers and bearers.

The data sheets and the general processes of USP and sleeper with USP are described in Annex F and Annex G.

If a tested USP is used with different concrete sleepers or bearers (different types or different manufacturing process), the purchaser shall state, as a selection of in Tables 3 to 5 given tests, which tests shall be performed.

5.2 Summary of design approval tests and routine tests

The design approval tests and the routine tests consist of the following three stages:

— Tests of USP alone and of USP on concrete block (see Table 3);

— Tests of concrete sleepers and bearers without USP (see Table 4);

— Tests of USP on concrete sleepers and bearers (see Table 5).

The frequency of routine tests is defined according to the quality plan of the suppliers (see Clause 8).

Table 3 — Tests of USP alone and of USP on concrete block

Tests	Subclause	Design approval tests	Routine tests
Tensile strength of USP material	5.3.1	Optional	Optional
Static and low frequency dynamic bedding modulus of USP on concrete block with GBP	5.3.2	Mandatory for static, 5 and 10 Hz, optional for 20 and 30 Hz	1 of 2 is Mandatory
Static and low frequency dynamic bedding modulus of USP alone with GBP	5.3.3	Optional	
Higher frequency dynamic bedding modulus of USP on concrete block	5.3.4	Optional (but recommended if USP is used for vibrations attenuation)	Not Applicable
Fatigue test of USP on concrete block	5.3.5	Mandatory	Not Applicable
Fatigue test of USP on concrete block with GBP	5.3.6	Optional (but recommended if USP is used for vibrations attenuation)	Not Applicable
Capability for stacked stocking of sleepers with USP on concrete block	5.3.7	Optional	Not Applicable
Effect of severe environmental conditions on USP on concrete block	5.3.8	Optional	Not Applicable
Resistance to water (Hydrolysis)	5.3.9	Optional	Not Applicable
Resistance to chemical agents related to the manufacture of sleepers or bearers	5.3.9	Optional	Not Applicable
Resistance to fire	5.3.9	Optional	Not Applicable
Resistance to hydrocarbon	5.3.9	Optional	Not Applicable
Resistance to ozone	5.3.9	Optional	Not Applicable

Table 4 — Tests of concrete sleepers and bearers without USP

Tests	Subclause	Design approval tests	Routine tests
Requirements of concrete sleepers and bearers	5.4	Mandatory	Mandatory

Table 5 — Tests of USP on concrete sleepers and bearers

Tests	Subclause	Design approval tests	Routine tests
Dimensions and masses of sleepers and bearers with USP	5.5.1	Mandatory	Mandatory
Bond strength by pull-out of USP on sleeper and bearer	5.5.2	Mandatory	Mandatory
Fatigue test of USP on sleeper	5.5.3	Optional	Not Applicable
Environment and end of life	5.5.4	Optional	Not Applicable

5.3 Tests of USP alone and of USP on concrete block

5.3.1 Tensile strength of USP material

The tensile strength measured during the design approval tests shall determine the reference value of these tensile strengths to confirm the quality of the USP during the routine tests. The test should permit the measurement of the tensile strengths both parallel and perpendicular to the production direction of USP (if there is a difference in production direction).

a) Test arrangement:

The test is performed on USP in accordance with the EN ISO 527-series or ISO 37 and with the supplier's indications which are approved by the purchaser. The test shall be done on the USP without bonding and protection layer. The supplier shall specify the thickness of the samples.

NOTE For USP materials not considered by these two standards, adaptation on the sample size may be allowed, in accordance with the purchaser.

b) Design approval tests:

The test method shall be applied on 6 tested samples (3 samples are stamped out parallel to the production direction of USP and 3 samples perpendicular to the production direction of USP).

The supplier shall provide a reference value of tensile strength within the range of purchaser's acceptance values.

5.3.2 Static and low frequency dynamic bedding modulus of USP on concrete block with GBP

The static and the low frequency dynamic bedding modulus of the USP on concrete block with GBP allow the bedding modulus of the USP to be quantified without the influence of manufacturing process of the sleepers.

a) Test arrangement:

The static and low frequency dynamic bedding modulus of the USP on concrete block with GBP shall be measured in accordance with Annex C.

The low frequency dynamic bedding modulus is measured at (5 ± 1) Hz and (10 ± 1) Hz (and optional frequency tests at (20 ± 2) Hz and (30 ± 3) Hz).

b) Design approval tests:

The test method shall be applied on 3 concrete blocks with USP.

The purchaser shall define the evaluation criteria(s) within the list:

1) purchaser minimum value ≤ C_{stat} ≤ purchaser maximum value (average or/and individual value);

2) purchaser minimum value ≤ $C_{dyn,\ 5\ Hz}$ or $C_{dyn\ 10\ Hz}$ ≤ purchaser maximum value (average or/and individual value).

The supplier shall provide a reference value of bedding modulus for routine test, in the range of purchaser acceptance values.

5.3.3 Static and low frequency dynamic bedding modulus of USP alone with GBP

The static and the low frequency dynamic bedding modulus of the USP alone with GBP allows the vertical bedding modulus of the USP to be quantified without the influence of a bonding system in concrete. This method requires a USP without a bonding system or with a bonding system which has no influence on the bedding modulus.

The static and low frequency dynamic bedding modulus measured during the design approval tests shall determine the reference value of these bedding moduli to follow the quality of the production of USP during the routine tests

NOTE 1 The values of bedding modulus with and without concrete block may be different.

a) Test arrangement:

The static and low frequency dynamic bedding modulus of USP alone with GBP shall be measured in accordance with Annex C.

The low frequency dynamic bedding modulus is measured at (5 ± 1) Hz and (10 ± 1) Hz (and optional frequency tests at (20 ± 2) Hz and (30 ± 3) Hz).

b) Design approval tests:

The test method shall be applied on 3 USP alone.

The supplier shall provide a reference value of bedding modulus for routine test, within the range of the results.

NOTE 2 The bedding modulus with and without concrete block are not necessarily the same values.

5.3.4 Higher frequency dynamic bedding modulus of USP on concrete block

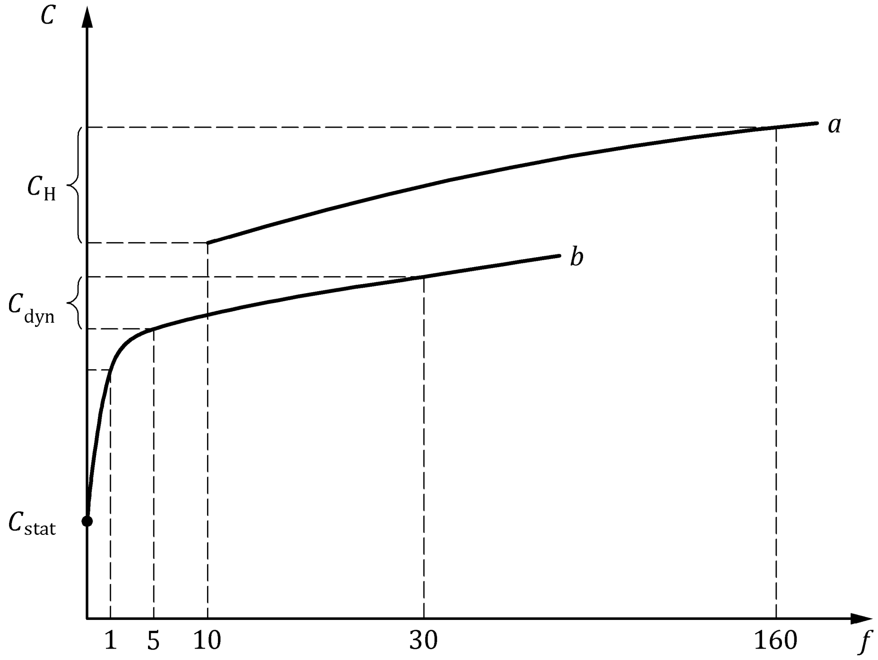
This test evaluates the capacity of USP to insulate vibrations.

a) Test arrangement:

The higher frequency dynamic bedding modulus of USP on concrete block with GBP shall be measured in accordance with Annex H. The testing procedure and equipment are different to the determination of low frequency dynamic bedding modulus.

NOTE 1 In contrast to the test of the low frequency dynamic bedding modulus C_{dyn}, the test procedure to measure the higher frequency dynamic bedding modulus C_H is carried out with static preloading and with smaller vibration amplitude. For this reason the values of the two moduli are not the same when measured at the same frequency, e.g. at 20 Hz, C_H (20 Hz) ≠ C_{dyn} (20 Hz). (see Figure 1).

NOTE 2 The magnitude of the loss factor η of a USP influences the dynamic magnification in the region of the natural frequency of the elastically supported track as an oscillatory system. It determines the edge steepness of the amplitude response and thus the insertion loss of the overall system (see H.3).



Key

a curve for higher frequency dynamic bedding modulus

b curve for static and low frequency dynamic bedding modulus

C bedding modulus, in N/mm^3

f frequency, in Hz

Figure 1 — Example of a frequency-dependant bedding modulus curve (with and without preloading force)

b) Design approval tests:

The test method shall be applied on one USP on concrete block.

The purchaser shall define the evaluation criteria.

5.3.5 Fatigue test of USP on concrete block

This test evaluates the durability of USP in contact with ballast. This fatigue test permits the evaluation of the interaction of the ballast with USP.

a) Test arrangement:

The fatigue test of the USP on concrete block shall be carried out in accordance with Annex D.

b) Design approval tests:

The test method shall be applied on one USP on concrete block.

Visual inspection shall be according to the purchaser's criteria.

5.3.6 Fatigue test of USP on concrete block with GBP

This test evaluates the durability, stability of bedding modulus and vibration characteristics (in case of use for vibration applications) of USP in contact with GBP. This test permits the evaluation of the long term variation of bedding modulus of USP.

a) Test arrangement:

The fatigue test of USP on concrete block shall be measured in accordance with Annex I.

b) Design approval tests:

The test method shall be applied on one USP on concrete block.

The purchaser shall define the evaluation criteria in the list:

1) ΔC_{stat} ≤ purchaser value;

2) $\Delta C_{dyn\ 5\ Hz}$ ≤ purchaser value.

5.3.7 Capability for stacked stocking of sleepers with USP, testing by USP on a concrete block

This test permits the impact on the USP when stacked in storage to be quantified.

a) Test arrangement:

The capability for stacked stocking of USP shall be measured in accordance with Annex J.

The purchaser defines the test pressure p_{test}.

Example of calculation of p_{test}: p_{test} = (safety coefficient) x 0,8 N/mm² (15 sleepers of 3 000 N each on two wood battens with a contact section with USP of 280 mm x 100 mm ≥ 0,8 N/mm²).

NOTE Safety coefficient is between 1 and 1,2 depending on rail seat inclination and size of battens.

The USP manufacturer chooses the test pressure p_{test}. Results are valid for all the values less or equal to the test load.

b) Design approval tests:

The test method shall be applied on one USP on concrete block.

Visual inspection shall be according to the purchaser criteria.

The purchaser shall define the evaluation criteria in the list:

1) ΔC_{stat} ≤ purchaser value;

2) $\Delta C_{dyn\ 5\ Hz}$ ≤ purchaser value;

3) variation of thickness of the USP ≤ purchaser value.

5.3.8 Effect of severe environmental conditions on USP on concrete block

This test evaluates the durability of sleepers with USP with respect to the cycles of the seasons. This effect of severe environmental conditions test shall quantify the effects of the seasons on USP.

The variations of static and the low frequency dynamic bedding modulus of USP on concrete block with GBP are measured in accordance with Annex C in order to quantify the variation of bedding modulus characteristics after the effect of severe environmental conditions of USP on concrete block.

a) Test arrangement:

The effect of severe environmental conditions of USP on concrete block shall be measured in accordance with Annex N.

b) Design approval tests:

The test method shall be applied on one USP on concrete block.

Visual inspection shall be according to the purchaser criteria.

The purchaser shall define the evaluation criteria in the list:

1) (ΔC_{stat} or $\Delta C_{\text{dyn 5 Hz}}$) ≤ purchaser value;

2) average value of at least 3 pull-out tests ≥ purchaser average value;

3) minimum value of at least 3 pull-out tests ≥ purchaser minimum value.

5.3.9 Resistance to other environmental parameters

The chemical agents used for the production of the USP should not modify the properties of the sleepers or bearers. The purchaser shall define test methods.

Water, Hydrocarbons and Ozone (in track) shall not modify significantly the material characteristics of USP. The test is performed with the supplier's instructions which are approved by the purchaser.

In case of fire the USP should not propagate the fire or create toxic fumes. The purchaser shall define test methods. The requirements can be different for tunnel, station or open track.

The purchaser shall define the evaluation criteria and the number of samples for:

1) resistance to chemical agents related to the manufacture of sleepers or bearers;

2) resistance to water (hydrolysis);

3) resistance to hydrocarbon;

4) resistance to ozone;

5) resistance to fire.

5.4 Tests of concrete sleepers and bearers without USP

The sleeper or bearer shall fulfil the requirements given in the EN 13230 series. The purchaser shall define performances of concrete sleepers or bearers used.

5.5 Tests of USP on concrete sleepers and bearers

5.5.1 Dimensions and masses of sleepers and bearers with USP

Dimension of the USP shall fit to the dimensions of the concrete sleeper/bearer bottom surface.

USP may cover the whole or part of the bottom surface of the sleeper or bearer.

USP geometry and position at sleeper bottom surface shall take into account events during lifetime: storage before use, track laying works, maintenance works in track.

The dimensions of USP shall take into account potential damage of the sleeper/bearer with USP in case of misuse during tamping.

The embedment of the USP shall have no effects to the load capacity of the sleeper or bearer. This means that embedment leads to no depth reduction of the concrete part of the sleeper.

Embedment of the USP in the concrete sleeper/bearer shall fulfil requirements for the concrete cover on steel as defined in EN 13230-1:2016.

The dimensions and the masses of sleepers and bearers with USP shall be defined by the purchaser in order to control the mass of sleepers and the thickness of sleepers and shall not disrupt the maintenance operation (tamping for example) and the installation of sleepers in track.

a) Test arrangement:

Dimensions and masses are measured with suitable instruments (instruments accepted by the purchaser).

b) Design approval tests:

The purchaser shall approve the drawing and technical documentations given by the supplier.

All the samples for design approval tests shall be checked according to the drawing and technical documentations.

5.5.2 Bond strength by pull-out of USP on sleeper and bearer

The bond strength by pull-out of USP on sleepers and bearers permits the bonding efficiency of the USP on concrete sleepers to be quantified.

The pull-out bond strength measured during the design approval tests shall determine the reference value to be used to verify the quality of the production of USP during the routine tests.

a) Test arrangement:

The bond strength by pull-out of USP on sleeper and bearer with USP shall be measured in accordance with Annex E.

b) Design approval tests:

The test method shall be applied on 3 concrete sleepers or bearers with USP with 4 pull-out tests per sleeper.

The average of 12 measurements of pull-out σ_{av} shall be calculated.

Average value ≥ purchaser average value.

Minimum value ≥ purchaser minimum value.

5.5.3 Fatigue test of USP on sleeper

This requirement is to verify the durability of sleepers with USP in contact with ballast. This ballast attrition resistance test shall quantify the impact of the ballast on USP on sleeper in function of the variation of characteristics of USP on sleeper.

The variations of static and the low frequency dynamic bedding modulus of USP on sleepers with GBP are measured in accordance with Annex K in order to quantify the variation of bedding modulus characteristics after the fatigue test of USP on sleeper.

NOTE 1 The bedding modulus measured with this methodology cannot be compared to the bedding modulus on a block

a) Test arrangement:

The ballast attrition resistance of sleeper and bearer with USP shall be measured in accordance with Annex L or Annex M.

NOTE 2 At the moment, there is not enough feedback to be able to compare the test results. There is no ranking or equivalence between the two tests. The test in Annex M (Alternative test procedure for fatigue test behaviour with of USP applied on sleeper) has been designed to be equivalent to the test in Annex L (Vibrogir): loads, number of cycle, etc.

b) Design approval tests:

The test method shall be applied on one sleeper with USP.

Visual inspection shall be according to the purchaser criteria.

$\Delta m \leq$ purchaser value, in %.

The purchaser should ask to test the concrete sleeper or bearer (of the same batch) without USP in the same conditions in order to have a reference about visual inspection and variation of mass.

5.5.4 Environment and end of life

If there are national regulations concerning environment and end-of-life, the sleeper with USP should follow these regulations.

The USP should not be an element of the track which pollutes the environment.

The USP should not adversely affect the recyclability of the concrete sleeper or bearer.

6 Data to be supplied

6.1 General

The purchaser can require data according to 6.3.2 from the supplier before the design approval tests.

The supplier shall supply all data of the USP and of the concrete sleeper with USP.

The general process of the design approval tests is described in informative Annex G.

6.2 Data supplied by the purchaser

The purchaser shall specify the following data:

a) all data for the concrete sleeper and bearer as defined in EN 13230-1:2016, 4.4.2;

b) track category;

c) drawings and specifications necessary to define:

   1) critical dimensions of the USP including tolerance (length, width, etc.) (see 5.5.1);

   2) geometry and position of USP on the sleeper including tolerance (see 5.5.1);

d) requirement for static and low frequency dynamic bedding modulus of USP on concrete block with GBP (see 5.3.3);

e) requirement for fatigue test with USP on concrete block (see 5.3.6);

f) requirement for bond strength of pull-out of the USP on sleeper (see 5.5.2);

g) for each optional test selected, the purchaser shall specify the relevant evaluation criteria for:

1) requirement for tensile strength of USP (see 5.3.1);
2) requirement for static and low frequency dynamic bedding modulus of USP alone (see 5.3.3);
3) requirement for higher frequency dynamic bedding modulus of the USP (see 5.3.4);
4) requirements for fatigue test with USP on concrete block, with GBP (see 5.3.6);
5) requirement for capability for stacked stocking of sleepers with USP on concrete block (see 5.3.7);
6) requirements for resistance of USP to water (see 5.3.9);
7) requirements for resistance of USP to fire (see 5.3.9);
8) requirements for resistance of USP to hydrocarbon (see 5.3.9);
9) requirements for resistance of USP to ozone (see 5.3.9);
10) requirements for resistance of USP to chemical agents (see 5.3.9);
11) requirements for fatigue test with USP applied on sleeper (see 5.5.3);
12) requirements for severe environmental conditions of sleeper/bearer with USP (see 5.3.8);
13) requirements for environment and end of life conditions for sleeper/bearer with USP (see 5.5.4).

6.3 Data supplied by the supplier of sleeper with USP

6.3.1 General

The supplier shall provide the following documentation to the purchaser in confidence.

6.3.2 Before the design approval tests

The sleeper supplier shall provide to the purchaser the following documentation prior to design approval tests:

a) all data for the manufacturing of the concrete sleeper and bearer as defined in EN 13230-1:2016, 4.4.3;

b) technical data sheet (Annex F) of the USP including relevant standards which apply to the materials;

c) detailed drawings of the USP;

d) detailed drawings of the sleeper with USP;

e) description of the manufacturing process for bonding of the USP on the sleeper.

6.3.3 After the design approval tests

The supplier shall provide to the purchaser the following documentation prior to the design approval tests:

a) design approval tests report for the USP and for USP on concrete block (including data to be used for routine tests);

b) design approval tests report for the sleepers and bearers without USP;

c) design approval tests report for the sleepers and bearers with USP.

6.3.4 Prior to first start-up of production

The supplier shall provide to the purchaser the following documentation prior to start of production:

a) all data required for the manufacturing of concrete sleepers and bearers as defined in EN 13230-1:2016, Clause 8;

b) quality manual from the USP manufacturer;

c) in addition, quality manual includes "Inspection and test plan" which details all tests and evaluation criteria derived from design approval tests on USP;

d) production file for manufacturing data as defined in the following:

   1) EN 13230-2:2016, Clause 5;

   2) EN 13230-3:2016, 7.1;

   3) EN 13230-4:2016, 6.1.

With the addition of manufacturing data for fixing USP on the concrete sleeper:

e) detailed procedure for handling and stacking concrete sleepers with USP.

7 Rules for use of sleepers and bearers with USP

The essential rules to be complied with for the storage, handling and laying in track of sleepers and bearers shall be stated in a document drawn up by the supplier and validated by the purchaser.

These rules can be the subject of an addition to the sleeper or bearer manufacturing process file.

8 Quality control

The supplier shall operate a quality system which is defined and maintained in a quality manual. This manual shall address all actions, functions and resources, procedures and practices concerned with achieving, and providing documentary evidence that, the quality of the delivered USP, concrete sleepers and bearers with USP and services that the supplier provides conforming to the agreed requirements. The quality manual of the USP and sleeper supplier shall include a quality plan respectively for the USP and for the concrete sleepers and bearers with USP which shall define and detail the following:

— the organization, structure and responsibilities;

— all the materials, processes and procedures for manufacturing, storing and transportation of the concrete sleepers and bearers with USP;

— all testing requirements;

— all other quality control procedures to ensure and verify that the USP, the concrete sleepers and bearers with USP and service provided are to the agreed requirements.

The purchaser shall have access to the quality manual at the premises of the supplier.

NOTE Guidance on quality systems is given in EN ISO 9000.

9 Marking, labelling and packaging

Where there is adequate space for legible marking and no effect on performance, each sleeper or bearer with USP shall be marked.

The marking and labelling shall be coordinated with the purchaser.

When components are packed in containers each container shall be labelled with details of the components and with the production batch number or date of manufacture.

Annex A
(normative)

Geometric Ballast Plate (GBP)

A.1 Design of the GBP

The design of the GBP shall be according to Figure A.1 and A.2.

The general tolerances are fine according to the EN ISO 22768- series.

A.2 Material of GBP

The steel material is 1.4301 according to the EN 10027 series.

Dimensions in millimetres

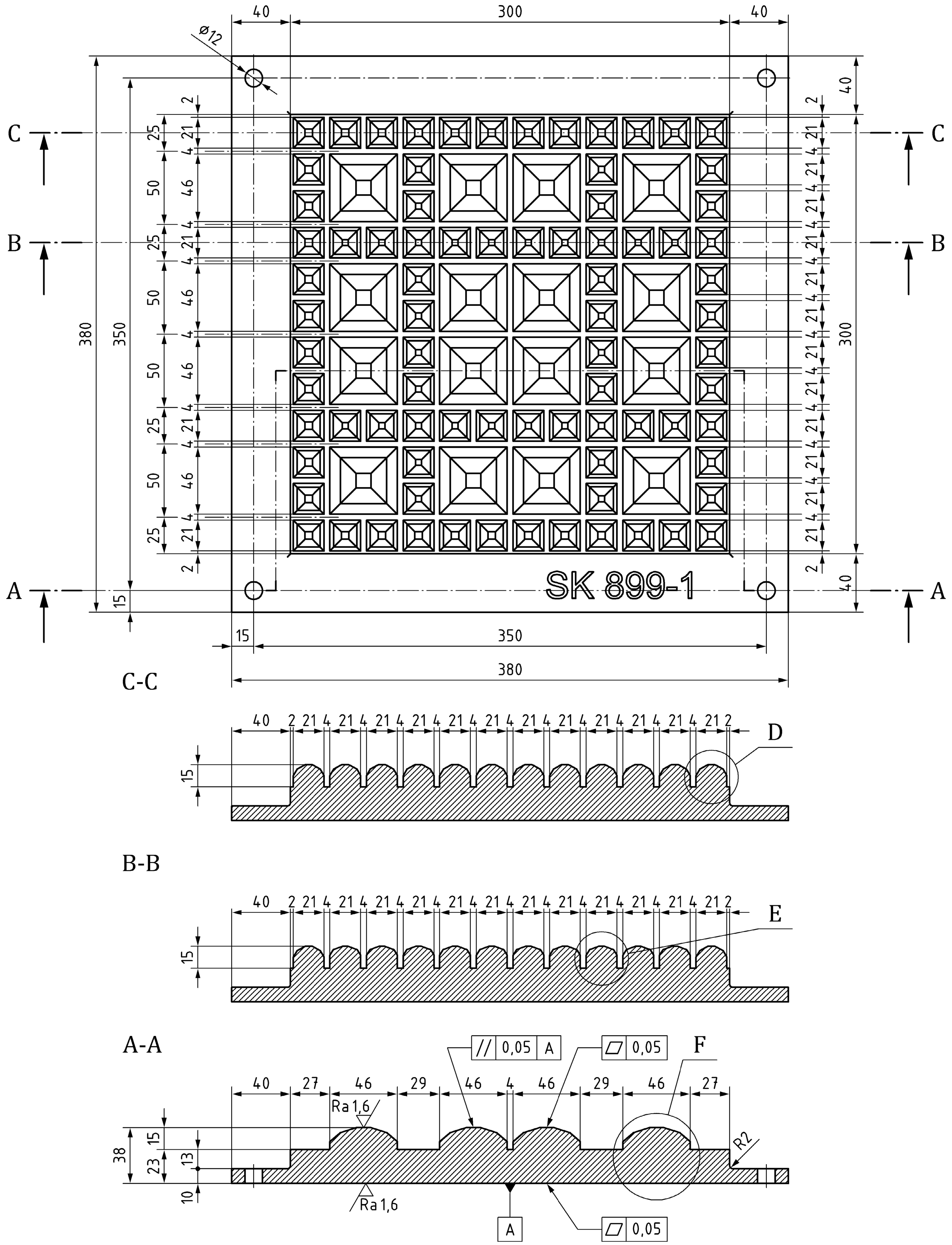
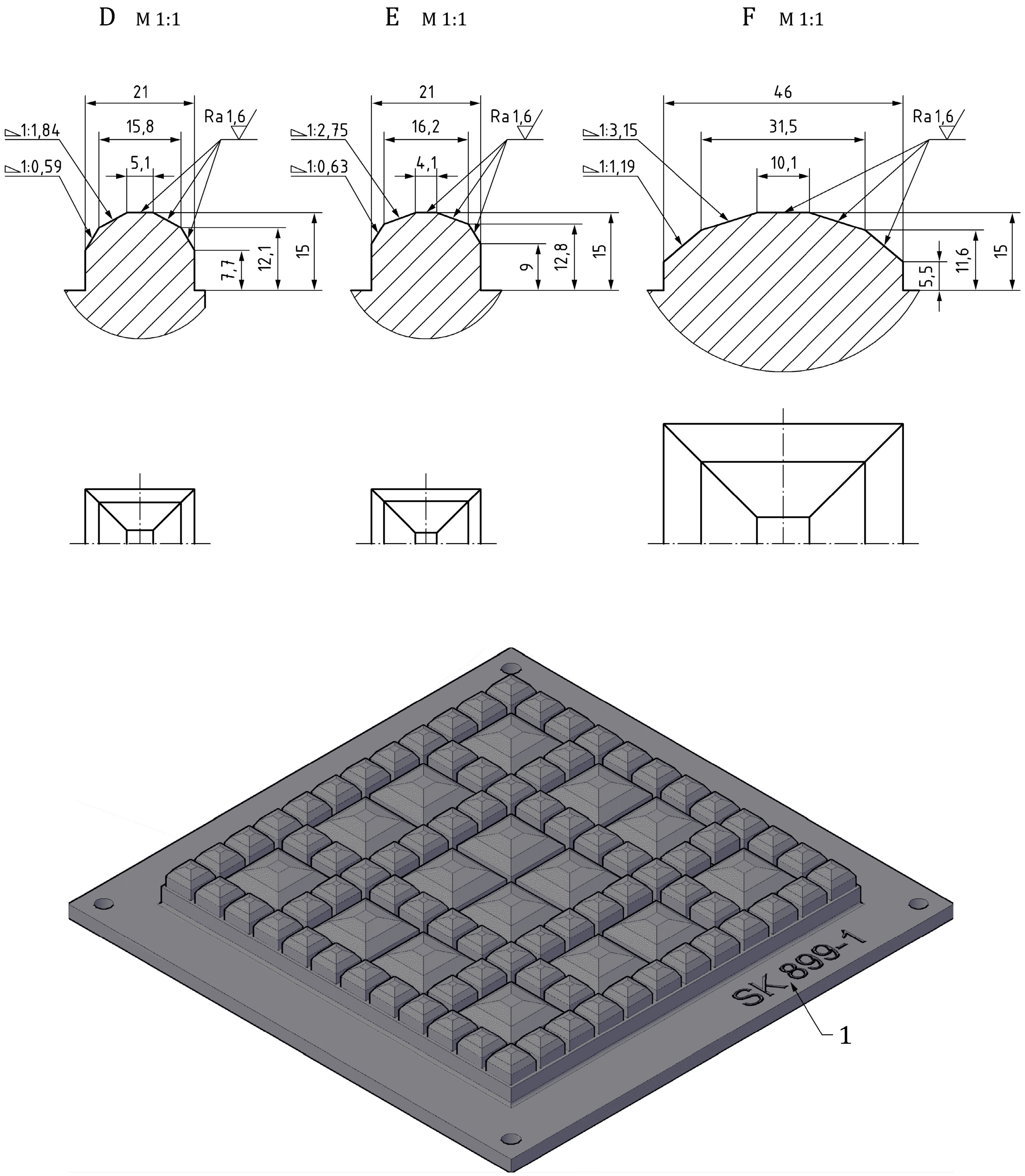


Figure A.1 — Drawing of GBP

Dimensions in millimetres



Key

D detail of the outer small pyramids

E detail of the inner small pyramids between the inner big pyramids

F detail of the inner big pyramids

1 original reference of GBP drawing (SK 899 – sequential number)

Figure A.2 — Drawing of GBP

Annex B
(normative)

USP on concrete block

B.1 Design of the USP on concrete block

Dimensions of test object: USP 250 mm × 250 mm × product thickness (see Figure B.1), on top of a concrete body with USP is cast (dimensions: 250 mm × 250 mm × 100 mm) as a substitute for the sleeper so the surface is A = 62 500 mm^2. The concrete body according to EN 206 shall be cast in suitable formwork (shuttering) and can be reinforced so that is capable of withstanding a test load of 30 kN. The bonding layer between the concrete body and the USP shall correspond to that between a concrete sleeper and the USP. The USP sample shall be the same as that the USP on concrete sleeper.

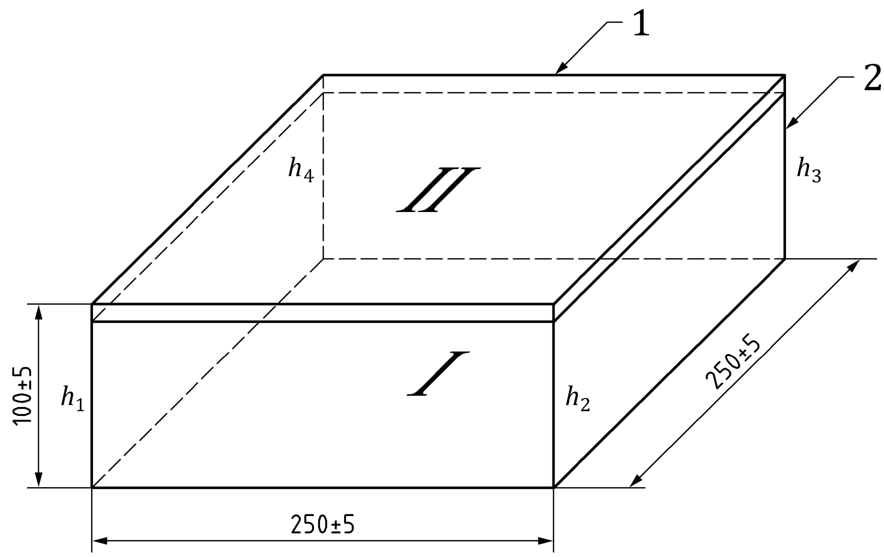
B.2 Tolerances of USP on concrete block

The surface of formwork shall have a planarity less than 0,2 mm over 250 mm. The tolerances of concrete blocks with USP are ((250 ± 5) mm × (250 ± 5) mm × (100 ± 5) mm). The maximum variation of height of 4 corners of USP on concrete block shall be not more than 1 mm. The gap between ruler and USP should be less than 1 mm on whole length.

The cast of the concrete block shall be done with the USP on one side due to the parallelism and roughness of the bottom and top surface of the block.

No correction on the surface "A" shall be done for samples with dimensions within (250 mm ± 5 mm) x (250 mm ± 5 mm). The surface A shall remain 62 500 mm^2. By design, the GBP gives the same contact surface within these tolerances of the sample.

Dimensions in millimetres



Key

Planarity of areas I+II in formwork ≤ 0,2 mm on 250 mm base length

Difference between any of h_1, h_2, h_3, h_4 ≤ 1,0 mm

Manufacturing: place USP on one side wall of formwork

1 USP

2 concrete block with bond USP

Figure B.1 — USP on concrete block

Annex C
(normative)

Static and low frequency dynamic bedding modulus of USP on concrete block or of USP alone with GBP

C.1 General

This test measures the bedding modulus of USP on concrete block or of USP alone.

C.2 Static test procedure

C.2.1 Principle

A force is applied normal to the USP on concrete block or the USP alone and the displacement is measured.

C.2.2 Apparatus

C.2.2.1 Controlled temperature test environment: the area of the laboratory where the test is conducted, maintained at (23 ± 5) °C.

When required by the purchaser, additional temperatures tests should be performed for the USP on concrete block at one or more of the following temperature: (−20 ± 3) °C, (0 ± 3) °C and (40 ± 3) °C.

C.2.2.2 GBP (geometric ballast plate) (see Annex A) connected to the actuator so that the effect of weight is included in the force F.

The GBP shall be clean, no corrosion and no oil.

C.2.2.3 USP on concrete block; see Annex B.

C.2.2.4 USP alone: dimensions of test object: USP 250 mm × 250 mm × product thickness so the area is A = 62 500 mm^2.

The tolerances of USP are ((250 ± 5) mm × (250 ± 5) mm). Even so the reference area for calculations shall be kept constant at A = 62 500 mm^2.

C.2.2.5 Abrasive cloth: sheets of abrasive cloth P220 or P240 in unworn condition.

Each sheet being not less than the full area of the pad to be tested.

C.2.2.6 Load plate: a rigid steel plate (minimum dimension 300 mm × 300 mm).

The load plate is connected with non-deformable support (key 1 of Figure C.1).

C.2.2.7 Actuator capable of applying a force of $1{,}1 \cdot F_{max}$.

NOTE Typically the maximum force is 25 kN.

C.2.2.8 Displacement measuring instruments: instruments complying with EN ISO 9513:2012, Table 2, class 1; when non-contact instruments are used they shall be calibrated to ensure the accuracy of measurement complies with the following requirements.

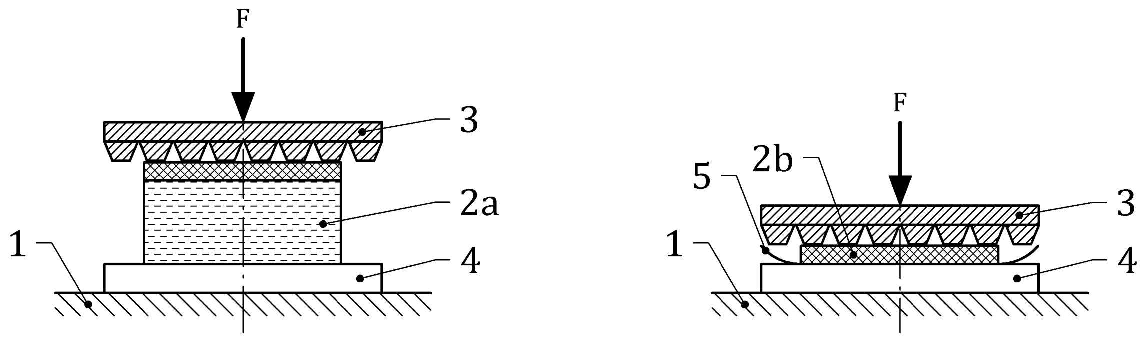
The instruments shall be capable of measuring the vertical displacement of the surface of the USP as follows:

— for USP with a declared/measured C_{stat} ≤ 0,2 N/mm³ displacement measurement within ± 0,02 mm;

— for USP with a declared/measured C_{stat} > 0,2 N/mm³ displacement measurement within ± 0,01 mm.

C.2.2.9 Force measuring instruments complying with EN ISO 7500-1, class 2 over the required range of force.

C.2.2.10 Recording equipment to make a digital recording and printout of the displacement and applied force.



Key

1 non-deformable support

2a USP on concrete block

2b USP alone

3 GBP (geometric ballast plate) (see Annex A) in contact with the USP

4 load plate (if necessary)

5 abrasive cloth (abrasive side up)

Figure C.1 — Test arrangement

C.2.3 Procedure

The flatness of the test area (on the two cross width of the block) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge. The USP shall be free of damage.

All components (USP on concrete block or USP alone, GBP and load plate) shall be at a temperature of (23 ± 5) °C or another specified temperature (for concrete block) prior to starting the test. Place the test set-up in the following sequence: flat rigid horizontal base, USP on concrete block or USP alone with abrasive cloth and GBP (where the centre of the plate coincides with the centre of USP on concrete block with a tolerance of position ± 3 mm) as shown in Figure C.1. In case of test with USP alone, the GBP may be installed under USP.

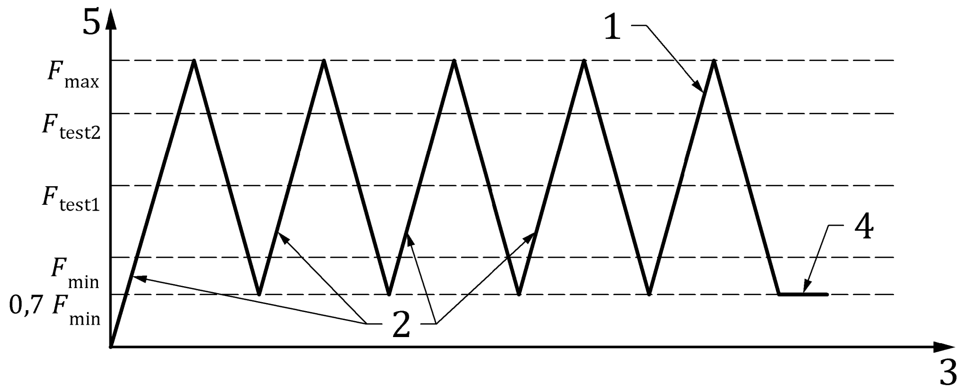
Locate enough independent instruments to measure the displacement between the GBP and the USP on concrete block or USP alone and check the rotation (minimum three displacement measuring instruments located at different corners of the plate). If the displacement measured by any of the instruments differs from the average displacement by ≥ 20 % of the maximum displacement, repeat the load cycle after at least (60 ± 5) s ensuring that the force is applied centrally to the USP on concrete block or the USP alone.

Table C.1 — Pressures for measurements of static and low frequency dynamic stiffness and bedding modulus

Track category	p_{min} N/mm²	p_{test1} N/mm²	p_{test2} N/mm²	p_{max} N/mm²
TC1	0,01	0,06	0,12	0,15
TC2		0,08	0,16	0,20
TC3		0,10	0,20	0,25
TC4		0,14	0,28	0,35

Apply a vertical force of ($F_{max} = p_{max} \cdot$ A) with the actuator (where the centre of GBP coincides with the axis of load), as specified in Table C.1. Then reduce the force to (0,7 × F_{min} with $F_{min} = p_{min} \cdot A$ as specified in Table C.1) and repeat this cycle of loading and unloading three times more with a rate of pressure application (0,01 ± 0,001) N/(mm²·s). Maintain the applied force (0,7 × F_{min}), then record the displacement while increasing the applied force to F_{max} (see Figure C.2).

If a dynamic bedding modulus is measured after the static bedding modulus test, the force is maintained to 0,7 × F_{min}.



Key

1 5th loading: temporal laps to record the displacement while increasing the applied force to F_{max}
2 first four load cycles preconditioning
3 time
4 if a dynamic bedding modulus is measured after the static bedding modulus test, the force is maintained to 0,7 × F_{min}
5 load

Figure C.2 — Load cycle graph

Calculate the static stiffness and static bedding modulus of the fifth load cycle from the following formula:

$$k_{stat} = \frac{F_{test1} - F_{min}}{d_{test1} - d_{min}} \quad (C.1)$$

$$C_{stat} = \frac{F_{test1} - F_{min}}{\left(d_{test1} - d_{min}\right) \cdot A} \quad (C.2)$$

where

F_{test1} $= p_{test1} \cdot A$ as specified in Table C.1

F_{min} $= p_{min} \cdot A$ as specified in Table C.1

d_{min} is the average displacement of all sensors when the applied force is increased from F_{min}

d_{test1} is the average displacement of all sensors when the applied force is increased from F_{test1}

A is the area of USP on concrete block or USP alone (62 500 mm²)

$$k_{tend} = \frac{F_{test2} - F_{min}}{d_{test2} - d_{min}} \tag{C.3}$$

$$C_{tend} = \frac{F_{test2} - F_{min}}{(d_{test2} - d_{min}) \cdot A} \tag{C.4}$$

where

the definitions are the same ones as above, except for F_{test2} and d_{test2}:

F_{test2} $= p_{test2} \cdot A$ as specified in Table C.1

d_{test2} the average displacement of all sensors when the applied force is increased from F_{test2}

C.2.4 Test report

The test report shall include at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) temperature of test;

g) load deflection curve (if demanded by purchaser);

h) values of F_{min}, F_{max}, F_{test1}, F_{test2}, d_{min}, d_{test1} and d_{test2};

i) static stiffness of each USP tested;

j) static stiffness of each USP on concrete block or each USP alone tested;

k) planarity of USP of every block.

C.3 Low frequency dynamic test procedure

C.3.1 Principle

This method is valid for frequencies in the range (2 to 30) Hz.

A cyclic force is applied, normal to the USP, through an actuator at a single specified frequency or, if a general value of low frequency dynamic bedding modulus is required, at two (+ two optional) constant frequencies. The resulting maximum and minimum displacements of the surface of the USP are measured at the maximum and minimum forces.

C.3.2 Apparatus

The following equipment used for the static test is also used in this test:

a) controlled temperature test environment (see C.2.2.1);

b) GBP (geometric ballast plate) (see C.2.2.2);

c) USP on concrete block (see C.2.2.3);

d) USP alone (see C.2.2.4);

e) abrasive cloth (see C.2.2.5);

f) load plate (see C.2.2.6);

g) displacement measuring instruments (see C.2.2.8).

C.3.2.1 Actuator capable of applying a force of up to 0,44·F_{max} at the required test frequencies.

NOTE Typically the maximum force is 10 kN.

C.3.2.2 Force measuring instruments complying with EN ISO 7500-1, class 2 over the required range of force and capable of measurement at a minimum of 20 times per cycle.

C.3.2.3 Recording equipment to make a digital recording and print out of the displacement and applied force at the required test frequencies with a sampling frequency of at least 20 times the loading frequency.

C.3.3 Procedure

The flatness of test area (on the two cross width of the block) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge. The USP shall be free of damage.

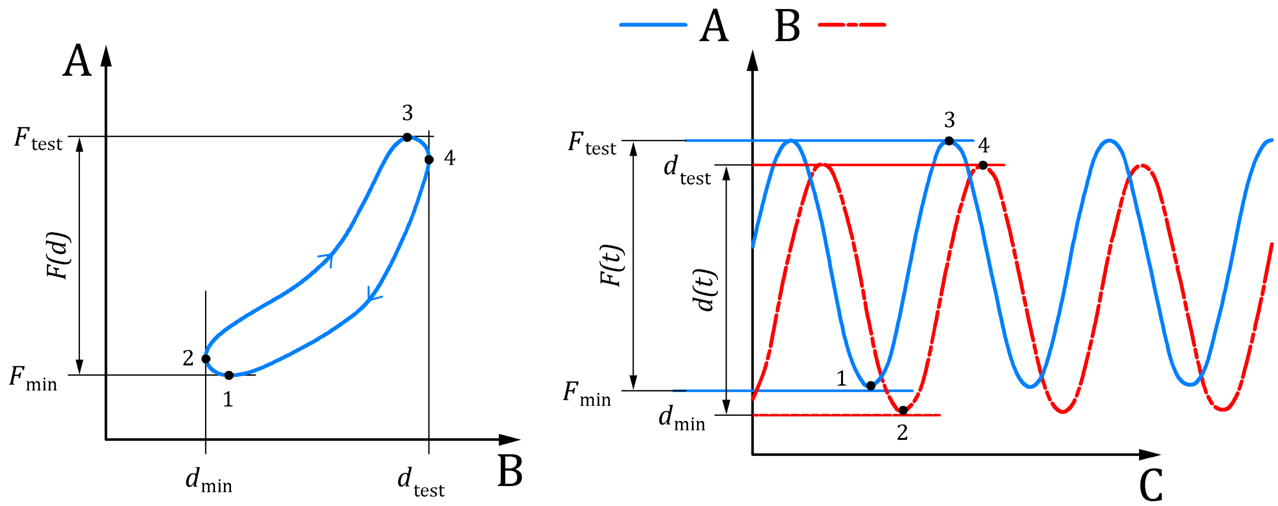
All components (USP on concrete block or USP alone, GBP and load plate) shall be at a temperature of (23 ± 5) °C or another specified temperature (for concrete block) prior to starting the test. Place the test set-up in the following sequence: flat rigid horizontal base, USP on concrete block or USP with abrasive cloth and GBP (where the centre of the plate coincides with the centre of USP on concrete block with a tolerance of position ± 3 mm) as shown in Figure C.1.

Locate enough independent instruments to measure the displacement between the GBP and the USP on concrete block or the USP alone and check the inclination of the plate (minimum three displacement measuring instruments located at different corners of the plate). If the displacement measured by any of the instruments differs from the average displacement by ≥ 20 % of the maximum displacement, repeat the load cycle after at least (60 ± 5) s ensuring that the force is applied centrally to the USP.

If the dynamic bedding modulus test is done after static bedding modulus test, then the dynamic bedding modulus test shall be done within (60 ± 5) s after the static bedding modulus test with a constant load of (0,7 · F_{min} with $F_{min} = p_{min} \cdot A$ as specified in Table C.1).

If a further dynamic bedding modulus test is to be done it shall be done within (60 ± 5) s after the previous one, with a constant load of ($F_{min} = p_{min} \cdot$ A as specified in Table C.1).

Apply a cyclic force of F_{min} (= $p_{min} \cdot A$) to F_{test} (= $p_{test1} \cdot A$) from Table C.1 at the specified frequency ± 1 Hz for 100 cycles (with 50 cycles maximum in order that the actuator applies the force amplitude demanded) or 10 s for frequencies > 10 Hz (with 5 s maximum in order that the actuator applies the force amplitude demanded).



Key

A force

B displacement

C time

1 F_{min}

2 d_{min}

3 F_{test}

4 d_{test}

Figure C.3 — Low frequency dynamic curves

Calculate the low frequency dynamic stiffness and low frequencies bedding modulus for 10 cycles recorded for each test frequency from the following formula:

$$k_{dyn} = \frac{1}{10} \cdot \sum_{i=1}^{10} \frac{F_{test,i} - F_{min,i}}{d_{test,i} - d_{min,i}} \quad (C.5)$$

$$C_{dyn} = \frac{k_{dyn}}{A} \quad (C.6)$$

$$\kappa_{dyn} = \frac{C_{dyn}}{C_{stat}} \quad (C.7)$$

where

F_{test} = $p_{test1} \cdot$ A as specified in Table C.1

F_{min} = $p_{min} \cdot$ A as specified in Table C.1

d_{min} is the average minimum displacement of all sensors

d_{test} is the average maximum displacement of all sensors

A is the area of USP on concrete block or USP alone (62 500 mm^2)

C.3.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) temperature of test;

g) mean load deflection curves (if demanded by purchaser);

h) values of F_{min}, F_{test}, $d_{min,}$ d_{test1} and d_{test2};

i) static stiffness of each USP on concrete block or each USP alone tested;

j) low frequency dynamic bedding modulus of each USP on concrete block or each USP alone tested;

k) stiffening coefficient of each USP tested;

l) frequency of the test;

m) planarity of USP of every block.

Annex D
(normative)

Fatigue test of USP on concrete block

D.1 Principle

Cyclic forces are applied vertically to the test setup USP for 3 million load cycles and the bedding modulus is measured before and after the fatigue test with USP applied on concrete block.

D.2 Apparatus

D.2.1 Controlled temperature test environment: the area of the laboratory where the test is conducted, maintained at (23 ± 5) °C.

D.2.2 Actuator capable of applying a force of $1{,}1 \cdot F_{test}$.

D.2.3 Displacement measuring instruments: instruments complying with EN ISO 9513:2012, Table 2, class 1; when non-contact instruments are used they shall be calibrated to ensure the accuracy of measurement complies with the following requirements.

The instruments shall be capable of measuring the vertical displacement of the surface of the test sleeper within ± 0,05 mm.

D.2.4 Force measuring instruments: instruments complying with EN ISO 7500-1, class 2 over the required range of force.

D.2.5 Recording equipment to make a digital recording and printout of the displacement and applied force.

D.2.6 Ballast defined by the customer, according to EN 13450, with a LA_{RB} 14 or less and M_{DE} RB 8 or less.

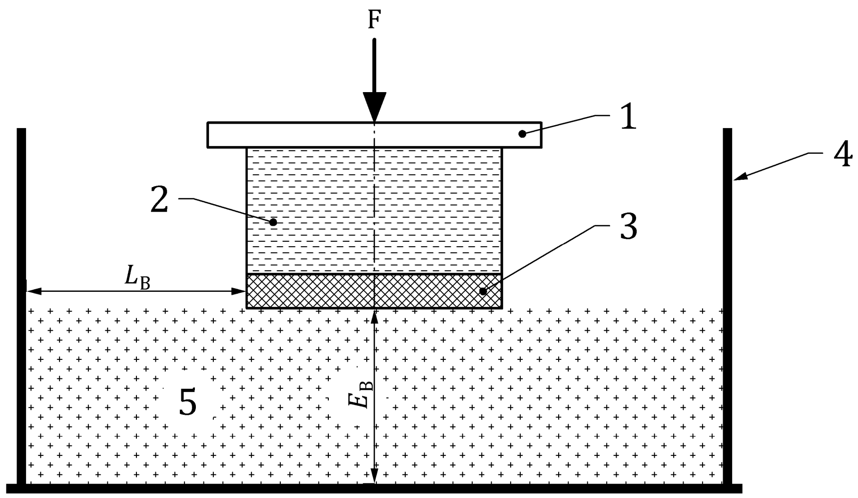
The ballast shall be new and shall not have been previously used for another test.

D.2.7 Load plate: a rigid steel plate (minimum dimension 300 mm × 300 mm).

The load plate is connected with the actuator and therefore, the effect of weight is included in the force *F*.

D.2.8 USP on concrete block; see Annex B.

D.2.9 Vibratory plate compactor: steel plate 350 mm × 350 mm × 40 mm with an external vibrator with 3 000 rpm (50 Hz) and a typical centrifugal force of 2 kN.



Key

1 load plate

2 concrete block with USP

3 USP

4 ballast box (non-deformable)

5 ballast with L_B ≥ 200 mm, E_B ≥ 200 mm

Figure D.1 — Test arrangement

D.3 Procedure

Before the fatigue test of USP on concrete block, the following information is taken:

— the USP shall be visually inspected for damage (perforation, cracking or other damage) as a result of the installation of the USP on the concrete block, during transportation or handling; the USP shall be free of damage;

— the static and lower frequency dynamic bedding modulus at 5 Hz are measured according to Annex C;

— the flatness of USP is measured. The flatness of test area (on the two cross width of the block) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge.

Place the test set-up in the following sequence: load plate, USP on concrete block and ballast as shown in Figure D.1.

Test loads are given in Table D.1.

Table D.1 — Maximum loads for fatigue test F_{max} (kN)

C_{stat} (N/mm³) for USP with concrete block / Track category	C_{stat} ≤ 0,1 N/mm³	0,1 < C_{stat} < 0,3 N/mm³	C_{stat} ≥ 0,3 N/mm³
	F_{max} (kN)	F_{max} (kN)	F_{max} (kN)
TC1	12	14	14
TC2	13	15	16
TC3	20	23	24
TC4	26	30	32

Apply a sinusoidal force:

— during 2 000 load cycles, the dynamic load is between the dynamic load 1 kN and $F_{max}/2$ of Table D.1 at the maximum frequency 5 Hz;

— during the following 2 000 load cycles, the dynamic load is between the dynamic load 1 kN and F_{max} of Table D.1 at the maximum frequency 5 Hz;

— during the following three million load cycles, the dynamic load is between the dynamic load 1 kN and F_{max} of Table D.1 at the maximum frequency 15 Hz.

When required by the customer, the displacement of actuator is measured.

Between 1 week (minimum) and 2 weeks (maximum) after the end of the fatigue test with USP on concrete block, the following information is taken (during this period, the USP is without load, means the block shall be stored turned with USP on top):

— the USP shall be visually inspected in order to look for evidence of damage (assessment of evidence of perforation, cracking or other damage);

— the static and lower frequency dynamic bedding modulus at 5 Hz are measured according to Annex C;

— the flatness of USP is measured; the flatness of test area (on the two cross width of the block) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge.

Calculate the variation of static and low frequency dynamic bedding modulus between before (be) and after (af) the fatigue test:

$$\Delta C_{\text{stat}} = \frac{\Delta C_{\text{stat,af}} - \Delta C_{\text{stat,be}}}{\Delta C_{\text{stat,be}}} \times 100\ [\%] \quad \text{(D.1)}$$

$$\Delta C_{\text{tend}} = \frac{\Delta C_{\text{tend,af}} - \Delta C_{\text{tend,be}}}{\Delta C_{\text{tend,be}}} \times 100\ [\%] \quad \text{(D.2)}$$

$$\Delta C_{\text{dyn,5Hz}} = \frac{\Delta C_{\text{dyn, 5Hz,af}} - \Delta C_{\text{dyn, 5Hz,be}}}{\Delta C_{\text{dyn, 5Hz,be}}} \times 100\ [\%] \quad \text{(D.3)}$$

D.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) value of F_{max};

g) results of visual inspection before and after the test with photos;

h) results of static and low frequency dynamic bedding modulus at 5 Hz before and after the test of each USP;

i) results of flatness before and after the test of each USP;

j) variations of bedding modulus of each USP.

Annex E
(normative)

Bond strength by pull-out of USP on sleeper and bearer

E.1 Principle

The bond strength of pull-out of USP on concrete sleepers permits to trace the quality of the production of system (USP on concrete sleeper).

E.2 Apparatus

E.2.1 Testing device.

The testing device shall be an apparatus according to EN 1542 or equivalent apparatus.

E.2.2 Samples of sleepers or bearers with USP.

The test is performed on samples of sleepers or bearers with USP.

E.3 Procedure

The USP shall be visually inspected for damage (perforation, cracking or other damage) as a result of the installation of the USP on the concrete block, during transportation or handling. Test area should be free of damage.

The test is performed on a sleeper or bearer with USP in accordance with EN 1542 and with the following parameters:

a) location: see Figures E.1 and E.2;

b) the bond strength between the USP and the concrete sleeper or bearer in the normal direction;

c) test temperature:

   1) ≥ 5°C (the sample is placed at temperature 24 h before the test) for routine tests;

   2) (23 ± 5) °C (the sample is placed at temperature 24 h before the test) for a design approval tests or for a check test of routine tests;

d) condition: dry;

e) diameter of the tear chip (test area): Ø (50 ± 1) mm;

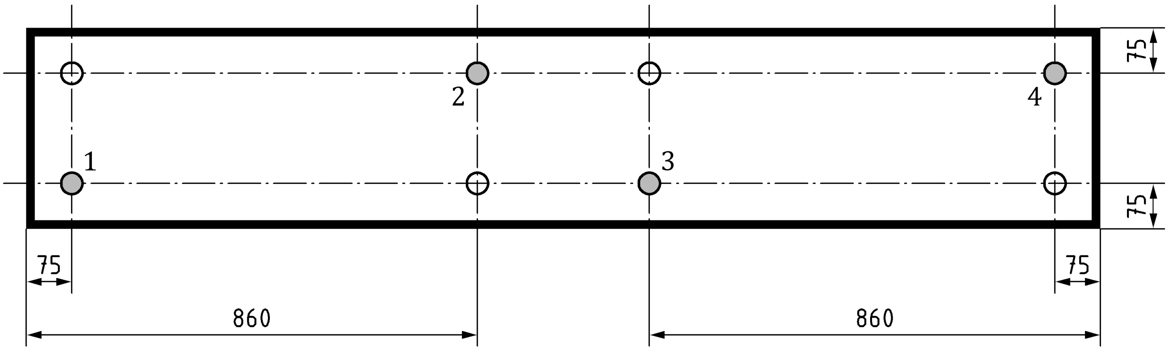
f) manner of load application: metal stud adhesively bonded to the under sleeper pad with bonding compound prepared in accordance with manufacturer’s instructions;

g) maximum loading speed: 0,01 $N/mm^2 \cdot s$;

h) the total drilling depth shall cut the bonding layer.

The test is carried out vertically to the bonded surface and continues until the test area detaches from the concrete body. The pull-out bond strength σ of each location (4 locations per concrete sleeper or bearer – see Figures E.1 and E.2) shall be determined according to EN 1542. The locations can be modified depending on the geometry of the sleepers.

Dimensions in millimetres



Key

1 location N° 1 of pull-out test on USP

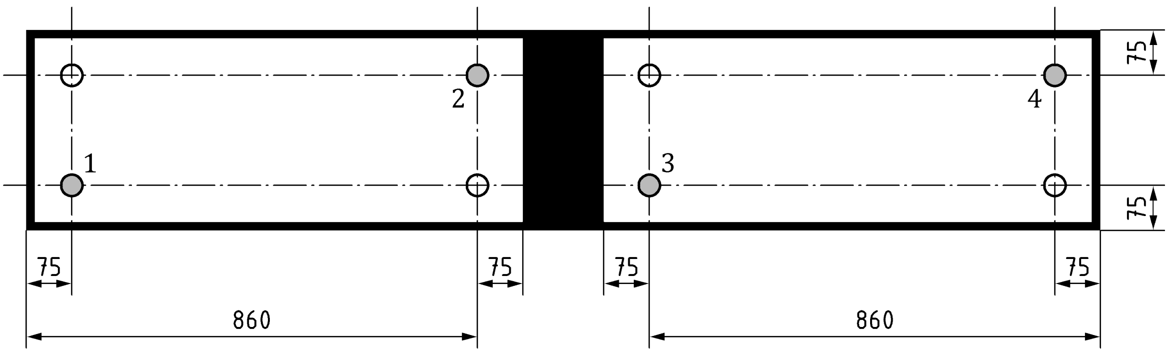
2 location N° 2 of pull-out test on USP

3 location N° 3 of pull-out test on USP

4 location N° 4 of pull-out test on USP

Figure E.1 — Example of location of pull-out test on USP which totally covers the bottom of the concrete sleeper or bearer

Dimensions in millimetres



Key

1 location N° 1 of pull-out test on USP

2 location N° 2 of pull-out test on USP

3 location N° 3 of pull-out test on USP

4 location N° 4 of pull-out test on USP

Figure E.2 — Example of location of pull-out test on USP which partially covers the bottom of the concrete sleeper or bearer

E.4 Test report

The test report shall include at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) bond strength of pull-out σ of every location of the concrete sleeper with USP tested;

g) results of visual inspection before the test.

Annex F
(normative)

Data sheet

F.1Data Sheet 1 (for USP Materials)

Parameter	Symbol	Value	Unit	Test Procedure	Remark
Material					Short description (e.g. PUR, CR, NR, RR, TPE, multi-layer, single layer, etc.)
Thickness			mm		
Design					Figure
Specific mass (mass per area)	m		kg/m²		
Tensile strength of USP material	σ		N/mm²	in accordance with EN 16730	Optional
Static and low frequency dynamic bedding modulus of USP on concrete block with GBP	C_{stat}, $C_{dyn,5\ Hz}$ or $C_{dyn,10\ Hz}$		N/mm³	in accordance with EN 16730 for (23 ± 5) °C	Additional indication of p_{test1}, p_{test2}, p_{min} Additional indication of p_{test}, p_{min}
Load-deflection curve	Graph C_{stat};C_{tend}			in accordance with EN 16730 for (23 ± 5) °C	
Static and low frequency dynamic bedding modulus of USP alone with GBP	C_{stat}, $C_{dyn,5\ Hz}$ or $C_{dyn,10\ Hz}$		N/mm³	in accordance with EN 16730	Optional
Higher frequency dynamic bedding modulus of USP on concrete block	Graph			in accordance with EN 16730	Optional (but recommended if USP is used for vibrations attenuation)
Fatigue test of USP on concrete block	ΔC_{stat} $\Delta C_{dyn,5\ Hz}$		%	in accordance with EN 16730	
Fatigue test of USP on concrete block with GBP	ΔC_{stat} $\Delta C_{dyn,5\ Hz}$		%	in accordance with EN 16730	Optional (but recommended if USP is used for vibrations attenuation)
Capability for stacked stocking of sleepers with USP on concrete block	ΔC_{stat} $\Delta C_{dyn,5\ Hz}$		%	in accordance with EN 16730	Optional Additional indication of p_{test}
Effect of severe environmental conditions on USP on concrete block	ΔC_{stat} $\Delta C_{dyn,5\ Hz}$ σ_{av} σ_{min}		% N/mm²	in accordance with EN 16730	Optional
Resistance to water					Optional
Resistance to chemical agents related to the manufacture of sleepers or bearers				in accordance with EN 16730; Purchaser defines the test method	Optional
Resistance to fire					Optional (but could be mandatory according to national laws)
Resistance to hydrocarbon					Optional
Resistance to ozone					Optional

NOTE The optional tests can be deleted from the data sheet if tests are not required.

F.2 Data Sheet 2 (for sleepers and bearers with USP)

Parameter	Symbol	Value	Unit	Test Procedure	Remark
Sleeper type					Name of Sleeper / Figure of bottom surface
Dimensions			mm		USP-area; recess from the sleeper edges; amount of USP-parts, etc.
Mass	m		kg		
Fixation method					e.g. bonding; type of interlocking layer, etc.
Bond strength by pull-out of USP on sleeper and bearer	σ_{av} σ_{min}		N/mm^2	in accordance with EN 16730	
Fatigue test of USP on sleeper	Δm		%	in accordance with EN 16730	Optional
Environment and end of life					Optional

NOTE The optional tests can be deleted from the data sheet if tests are not required.

Annex G
(informative)

General design approval tests and the routine tests for the USP and the sleeper with USP

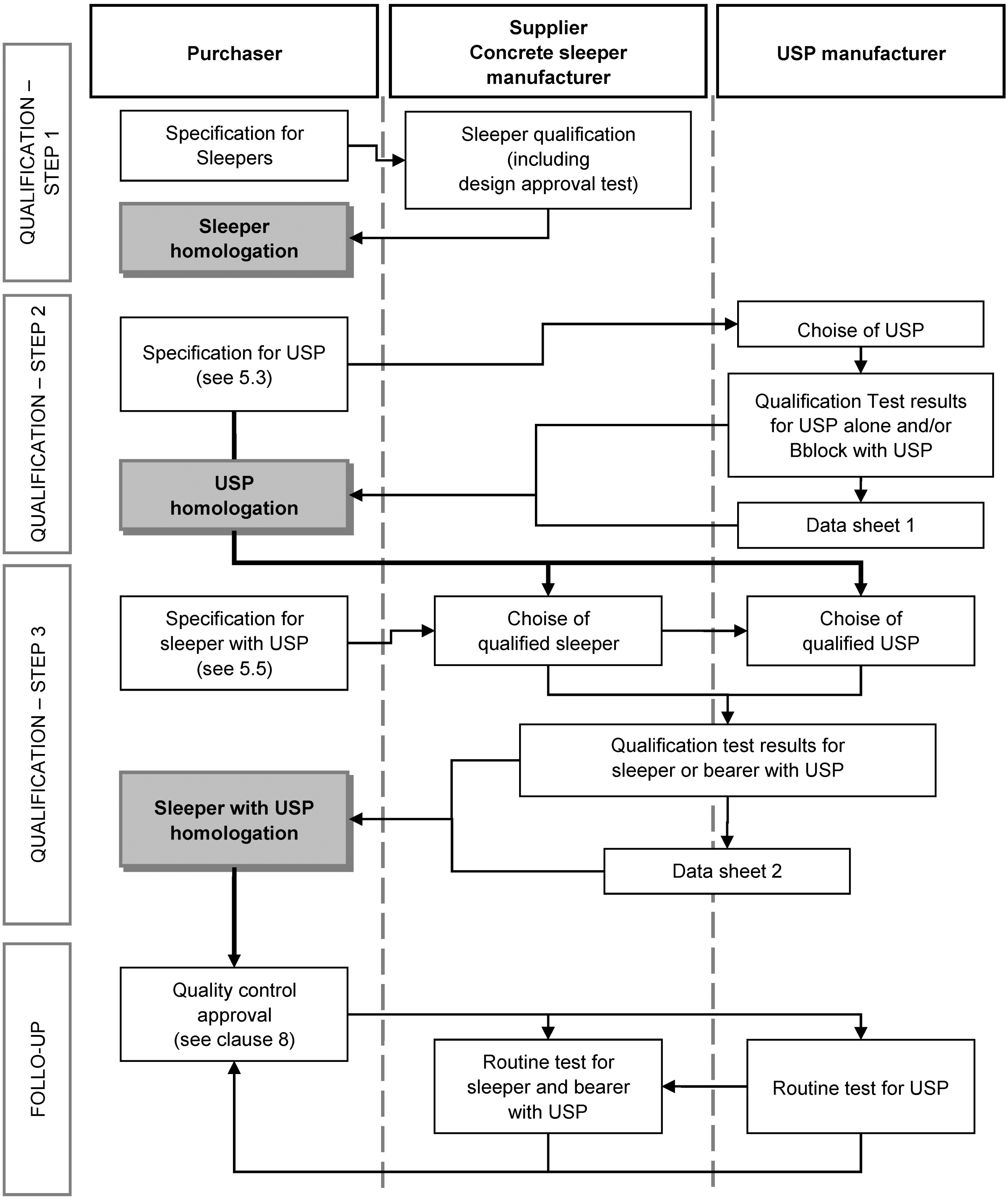


Figure G.1 — General process

Annex H
(informative)

Higher frequency dynamic vertical bedding modulus of USP on concrete block

H.1 Principle

Measurement of higher frequency vertical bedding modulus is performed for USP mitigation for vibration in ballasted track, particularly when mitigation of structure-borne noise and secondary airborne noise is required.

The magnitude of the dynamic bedding modulus $C_H(f)$ of a USP influences the natural frequency of the elastically supported track as an oscillatory system and thus the insertion loss.

The transfer bedding modulus is measured within a frequency range which corresponds to the frequencies usually used for those applications or in accordance with EN 16730.

The natural frequency of the system depends on the applied load, as well as on the bedding modulus of USP.

The natural frequency is calculated with the following formula: $f_0 = 1/2\pi \sqrt{(k/m)}$.

Measurement of higher frequency bedding modulus is performed using direct method as defined in EN ISO 10846-2.

In EN ISO 10846-2, measurement is performed up to a frequency of 450 Hz. For USP, the measurement range is reduced from 10 Hz up to at least 160 Hz frequency.

General principles related to these methods are indicated inside EN ISO 10846-1. They are valid if the vibration behaviour of the USP on concrete block is linear.

NOTE An alternative method like EN ISO 10846-5 may be proposed subject to evidence of suitability and approved by the customer with the reference method (EN ISO 10846-2).

H.2 Test arrangement

H.2.1 Test arrangement for the direct method

The centre of the GBP coincides with the centre of USP on concrete block with a tolerance of position ± 3 mm (see Annex A). The GBP shall be clean, with no corrosion or oil present.

After applying the static preload, the test sample shall be subjected to harmonic excitation at each of the test frequencies in succession so that the relative motion between the upper loading plate and the profiled loading plate GBP exhibits constant particle velocity amplitude.

Apply the static pre-loads as indicated in Table H.1 to the test setup as shown in Figure H.1.

Follow the test method as indicated in standard EN ISO 10846-2.

Test requires high foundation impedance as well as a typical static load and small dynamic loads in order to determine the transfer bedding modulus of USP on concrete block, considering them as linear elastic system inside the frequency range, used during the test.

Figure H.1 shows an arrangement drawing for the test apparatus.

It contains the following items:

— a frequency generator providing frequencies in accordance with the usual excitation frequency values used for these applications;

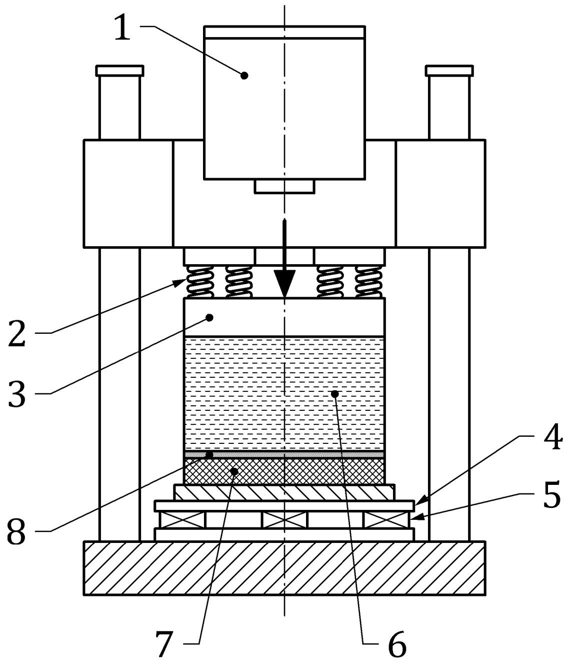
— a structure device able to balance the load, in order to apply the requested pre-load, as specified in Table H.1;

— vibrations insulators able to dynamically isolate the USP on concrete block from the structure, in accordance with the usual excitation frequencies values used for these applications;

— a pressure distribution plate which shall combine static and dynamic loads and balance the load on the total concrete block surface (up top to and down bottom, see Figure H.1)

— two acceleration measurement systems, one linked to the upper load distribution plate, and the other one linked to the force measurement platform, in order to measure the acceleration in accordance with the usual excitation frequencies values used for these applications;

— a force measurement system composed of several load transducers, working inside the range 0 kN up to maximum applicable force on the concrete block.



Key

1 frequency generator for isolated dynamic loads on the repartition load structure

2 static pre-load through elastic components

3 load distribution plate, acceleration measurement

4 top of the strength measurement platform, acceleration measurement

5 force measurement

6 USP on concrete block (see Annex B)

7 geometric ballast plate GBP (see Annex A)

8 USP

Figure H.1 — Direct method for transfer bedding modulus measurement

H.2.2 USP on concrete block

USP on concrete block; see Annex B.

H.2.3 Ambient Test temperature

All components used for the test shall be maintained at an average temperature of (23 ± 5) °C.

H.2.4 Vibration test velocity

The actual vibration velocity occurring on sleepers with USP in track shall be estimated for the USP on concrete block under test.

NOTE Type of load: Harmonic excitation with a particle velocity amplitude of 5 mm/s RMS (corresponding to a particle velocity level L_H = 100 dB relative to the standard reference particle velocity of 5×10^{-8} m/s).

H.3 Test procedure and evaluation

H.3.1 General

With the test arrangement as shown in Figure H.1, apply a static preload F_{pre} (= $p_{pre} \cdot A$) as specified in Table H.1. Follow the test procedure specified in EN ISO 10846-2.

Table H.1 — Pressures (in N/mm²) for high frequency dynamic vertical stiffness and bedding modulus

Track category	p_{pre} (N/mm²)
TC1	0,06
TC2	0,08
TC3	0,10
TC4	0,14

It is recommended to make the test for all preloads of Table H.1 to be able to interpolate intermediate values.

For each test frequency, the arithmetic mean value shall be calculated from the individual values for the three test objects (applies to the test at room temperature).

Measurements of force and deformation and the determination of dynamic bedding modulus shall take into account EN ISO 10846-2.

The dynamic bedding modulus $C_H(f)$ is the dynamic bedding modulus determined relative to the top surface of the test object.

To demonstrate the possible existence of a significant dependence of the dynamic bedding modulus on the size of the displacement amplitude, two values of the dynamic bedding modulus shall be recorded at the test frequency f = 80 Hz, one of which shall have been determined using a particle velocity level whose magnitude was 20 dB lower.

H.3.2 Loss factor η

H.3.2.1 General

The magnitude of the loss factor η of a USP influences the dynamic magnification amplification in the region of the natural frequency of the elastically supported track as an oscillatory system.

It determines the edge steepness of the amplitude response and thus the insertion loss of the overall system. In the test procedure described below, it is assumed that the USP behaves essentially linearly when the vibrational motion is centred on the static preload.

H.3.2.2 Test implementation and evaluation

When excitation is harmonic, the loss angle ζ shall be determined as the angular phase shift between the fundamental harmonic component of the applied force and the resulting deformation.

The loss factor η can then be determined from $\eta = \tan \zeta$.

Evaluation shall be carried out analogously to the method described in 5.3.4.

NOTE The degree of damping ϑ is approximately 21 tan ζ.

H.3.3 Higher frequency dynamic stiffening ratio κH (80 Hz)

The higher frequency dynamic stiffening ratio κ_H (80 Hz) at the test frequency f = 80 Hz shall be calculated as the quotient of the higher frequency dynamic bedding modulus, C_H, determined at L_H = 100 dB and 80 Hz, and the static bedding modulus, C_{stat}, as follows:

$$\kappa_H \text{ (80 Hz)} = C_H \text{ (80 Hz)} / C_{stat}$$

The values of the bedding moduli C_{stat} and C_H shall be determined on test specimen of identical area (Annex B).

H.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) test temperature;

g) value of p_{pre} used for the test;

h) dimension of sample;

i) a graph showing transfer bedding modulus versus frequency of each USP tested;

j) table of Loss factor from 10 Hz to 160 Hz in octave intervals of each USP tested;

k) higher frequency dynamic stiffening ratio κ_H (80 Hz) of each USP tested.

Annex I
(informative)

Fatigue test of USP on concrete block with GBP

I.1 Principle

A cyclic force is applied normal to the test USP setup for in total 3 million load cycles on GBP and the bedding modulus is measured before and after fatigue test of USP on concrete block.

I.2 Apparatus

I.2.1 Controlled temperature test environment: the area of the laboratory where the test is conducted, maintained at (23 ± 5) °C.

Additional tests may be specified in the technical specification and should be performed for USP on concrete block at one or more of the following temperatures: (−20 ± 3) °C, (0 ± 3) °C and (40 ± 3) °C.

I.2.2 GBP (geometric ballast plate): a rigid metal plate with the ballast profile face (see Annex A).

The GBP is connected with the actuator and therefore, the effect of its weight is included in the force F. The GBP shall be clean, with no corrosion or oil present.

I.2.3 USP on concrete block (see Annex B).

I.2.4 Load plate: a rigid metal plate (minimum dimension 300 mm × 300 mm).

The load plate is connected with non-deformable support (key 1 of Figure I.1).

I.2.5 Actuator capable of applying a force of $1,1 \cdot F_{max}$.

NOTE Typically the maximum force is 25 kN.

I.2.6 Displacement measuring instruments: instruments complying with EN ISO 9513:2012, Table 2, class 1; when non-contact instruments are used they shall be calibrated to ensure the accuracy of measurement complies with the following requirements.

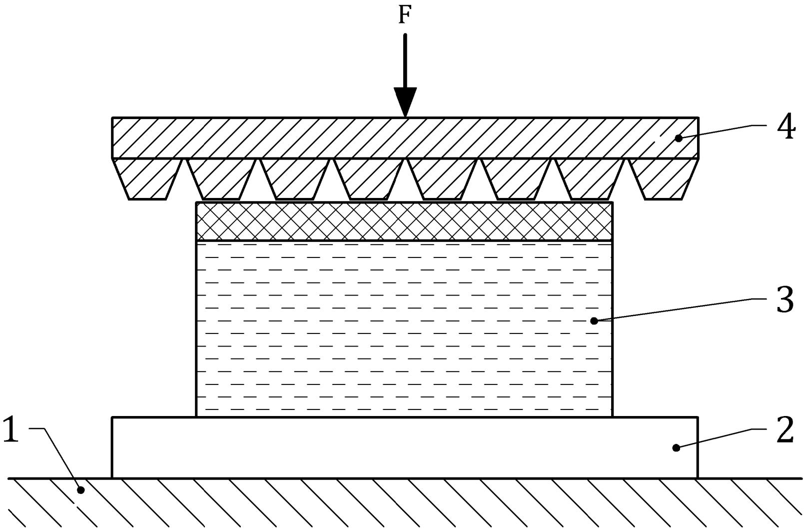
The instruments shall be capable of measuring the vertical displacement of the surface of the test pad as follows:

— for USP with a declared/measured $C_{stat} \leq 0,2$ N/mm³ displacement measurement within ± 0,02 mm;

— for USP with a declared/measured $C_{stat} > 0,2$ N/mm³ displacement measurement within ± 0,01 mm.

I.2.7 Force measuring instruments complying with EN ISO 7500-1, class 2 over the required range of force.

I.2.8 Recording equipment to make a digital recording and printout of the displacement and applied force.



Key

1 non-deformable support

2 load plate (if necessary)

3 concrete block with USP

4 GBP (geometric ballast plate) (see Annex A) in contact with USP on block

Figure I.1 — Test arrangement

I.3 Procedure

Before the fatigue test of USP on concrete block, the following information is taken:

— the USP shall be visually inspected for damage (perforation, cracking or other damage) as a result of the installation of the USP on the concrete block, during transportation or handling. The USP shall be free of damage;

— procedure for bedding modulus described in Annex C is realized two times measuring the static and low frequency dynamic bedding modulus at 5 Hz;

— the flatness of USP is measured. The flatness of test area (on the two cross width of the block) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge.

Place the test set-up in the following sequence: load plate, USP on concrete block with GBP as shown in Figure I.1.

Test loads are given in Table I.1 and 3 million cycles are applied.

Table I.1 — Pressures p_{max} (in N/mm²) for fatigue test

Track Category	$p_{(max)}$ (N/mm²)			
	$C_{dyn,5\ Hz} \le$ **0,04 N/mm³**	**0,04 N/mm³ <** $C_{dyn,5\ Hz} \le$ **0,15 N/mm³**	**0,15 N/mm³ <** $C_{dyn,5\ Hz} \le$ **0,25 N/mm³**	$C_{dyn,5\ Hz} >$ **0,25 N/mm³**
TC1 and TC2	0,09	0,09	0,12	0,12
TC3	0,09	0,12	0,15	0,15
TC4	0,12	0,15	0,18	0,21

Apply a sinusoidal force:

— the dynamic load is between the dynamic load F_{min} (with $F_{min} = p_{min} \cdot A$ with p_{min} = 0,01 N/mm²) and F_{max} ($F_{max} = p_{max} \cdot$ A as specified in Table I.1) at the frequency (3 to 10) Hz.

The displacements and the vertical force are measured for the first 100 cycles, another 100 cycles every 500 000 cycles and for the last 100 cycles of the 3 million cycles.

After the 3 million of cycles, the load applied on the block is F_{min}.

After the 3 million cycles and after 1 h the end of the test, the static and low frequency dynamic bedding modulus at 5 Hz are measured according to Annex C.

Between 1 week (minimum) and 2 weeks (maximum) after the end of the fatigue test with USP applied on concrete block, the following information is taken (during this period, the USP is without load and is the top of concrete block):

— the USP shall be visually inspected in order to look for evidence of damage (assessment of evidence of perforation, cracking or other damage);

— the static and low frequency dynamic bedding modulus at 5 Hz are measured according to Annex C;

— the flatness of USP is measured. The flatness of test area (on the two cross width of the block) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge.

Calculate the variation of static and low frequency dynamic bedding modulus ($C_{stat,be}$ and $C_{dyn,5\ Hz,be}$ are the values measured after the second bedding modulus test realized before fatigue test):

$$\Delta C_{stat} = \frac{\Delta C_{stat,af} - \Delta C_{stat,be}}{\Delta C_{stat,be}} \times 100\ [\%] \qquad (I.1)$$

$$\Delta C_{tend} = \frac{\Delta C_{tend,af} - \Delta C_{tend,be}}{\Delta C_{tend,be}} \times 100\ [\%] \qquad (I.2)$$

$$\Delta C_{dyn,5Hz} = \frac{\Delta C_{dyn,\ 5Hz,af} - \Delta C_{dyn,\ 5Hz,be}}{\Delta C_{dyn,\ 5Hz,be}} \times 100\ [\%] \qquad (I.3)$$

I.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) value of F_{max};

g) results of visual inspection before and after the test with photos;

h) results of static and low frequency dynamic bedding modulus at 5 Hz before and after the test of each USP tested;

i) results of flatness before and after the test of each USP tested;

j) variations of bedding modulus of each USP tested.

Annex J
(informative)

Capability of stacked storage of sleepers with USP

J.1 Principle

This test is to simulate the long term effect of compression of the USP when sleepers are stacked during storage.

J.2 Apparatus

J.2.1 Controlled temperature test environment: the area of the laboratory where the test is conducted, maintained at (23 ± 5) °C.

J.2.2 Load plate: a rigid metal plate (minimum dimension 300 mm × 300 mm).

The load plate is connected with the actuator and therefore, the effect of weight is included in the force F.

J.2.3 Batten: metal plate, fixed to load plate.

Dimensions are defined in Figure J.1.

J.2.4 USP on concrete block(see Annex B).

J.2.5 USP alone: dimensions of test object: USP 250 mm × 250 mm × product thickness so the area is A = 62 500 mm^2.

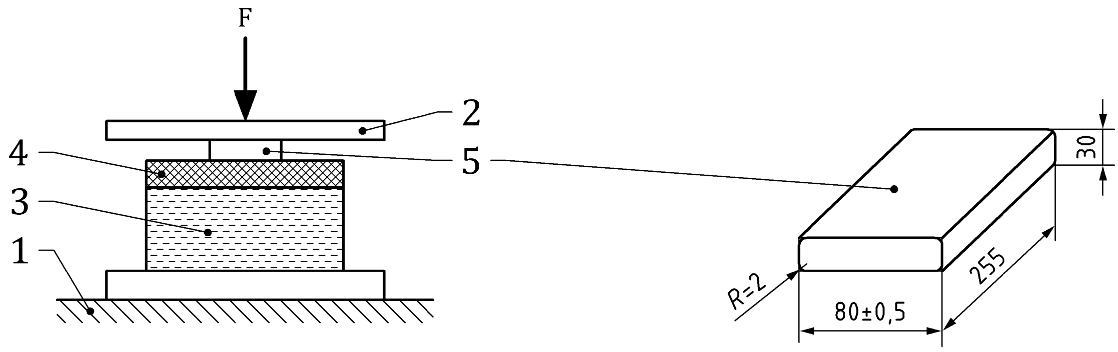
The tolerances of the USP are (250 ± 5) mm × (250 ± 5) mm.

J.2.6 Loading device capable of applying a pressure of 1,1 F_{test}.

NOTE Typically the maximum force is 50 kN.

J.2.7 Force measuring instruments: instruments with accuracy of ± 10 % of F_{test}.

Dimensions in millimetres



Key

1 non-deformable support

2 steel plate

3 concrete block with USP or USP alone with abrasive cloth

4 USP

5 batten

Figure J.1 — Test arrangement

J.3 Procedure

Before the test of capability for stacked stocking of USP, the following information is taken:

— the pad shall be visually inspected in order to look for damages (perforation, cracking or other damage) resulting of the installation of the USP on the concrete block, during the transport or of any handling; the USP shall be free of damage;

— the thickness of USP is measured.

All components (USP on concrete block or USP alone, GBP and load plate) shall be at a temperature of (23 ± 5) °C prior to starting the test. Place the test set-up in the following sequence: flat rigid horizontal base, metal plate, USP on concrete block or USP with abrasive cloth (where the centre of the USP coincides with the actuator with a tolerance of position ± 3 mm), load plate as shown in Figure J.1. Apply a force of ($F_{test} = p_{test} \cdot A$ as specified in 5.3.7) during 168 h. And reduce the force to 0 kN.

After the test of capability for stacked stocking of USP, the following information is taken:

a) the thickness of USP is measured in batten axis (between the batten and the top of the concrete block if tested on concrete block):

  1) 1 min after removing of the load;

  2) (24 ± 2) h after removing of the load;

  3) Between 1 week (minimum) and 2 weeks (maximum) after removing of the load;

b) the static and low frequency dynamic bedding modulus at 5 Hz are measured according to Annex C (24 ± 2) h after the end of the test;

c) just after the bedding modulus test, the USP shall be visually inspected in order to look for evidence of damage (assessment of evidence of perforation, cracking or other damage).

J.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) value of F_{test};

g) results of visual inspection before and after the test with photos;

h) results of thickness before and after the test of each USP tested;

i) results of static and low frequency dynamic bedding modulus at 5 Hz after the test of each USP tested.

Annex K
(informative)

Static and low frequency dynamic bedding modulus of USP on concrete sleeper or bearer with GBP

K.1 General

This test measures the bedding modulus of USP on sleepers or bearers. The variations of static and the low frequency dynamic bedding modulus of sleepers with USP with GBP permit the modification of the bedding modulus characteristics after a fatigue test to be quantified.

K.2 Static test procedure

K.2.1 Principle

A force is applied normal to the test USP with sleeper or bearer and the displacement is measured.

K.2.2 Apparatus

K.2.2.1 Controlled temperature test environment.

The area of the laboratory where the test is conducted, maintained at (23 ± 5) °C.

K.2.2.2 GBP (Geometric Ballast Plate) (see Annex A) which is connected with the actuator so that the effect of weight is included in the force F and which shall be clean, no corrosion and no oil.

Only a part of the surface of GBP is used for the stiffness test with sleeper. This surface A is projected surface between the USP and the GBP for measurement of the bedding modulus of USP. This surface A shall be measured.

K.2.2.3 Articulated support (see EN 13230-2:2016, Annex A for the details).

K.2.2.4 Tapered packing (see EN 13230-2:2016, Annex A for the details).

K.2.2.5 Actuator capable of applying a pressure of $1{,}1 \cdot F_{max}$.

NOTE Typically the maximum force is 60 kN.

K.2.2.6 Displacement measuring instruments: instruments complying with EN ISO 9513:2012, Table 2, class 1; when non-contact instruments are used, shall be calibrated to ensure the accuracy of measurement complies with the following requirements.

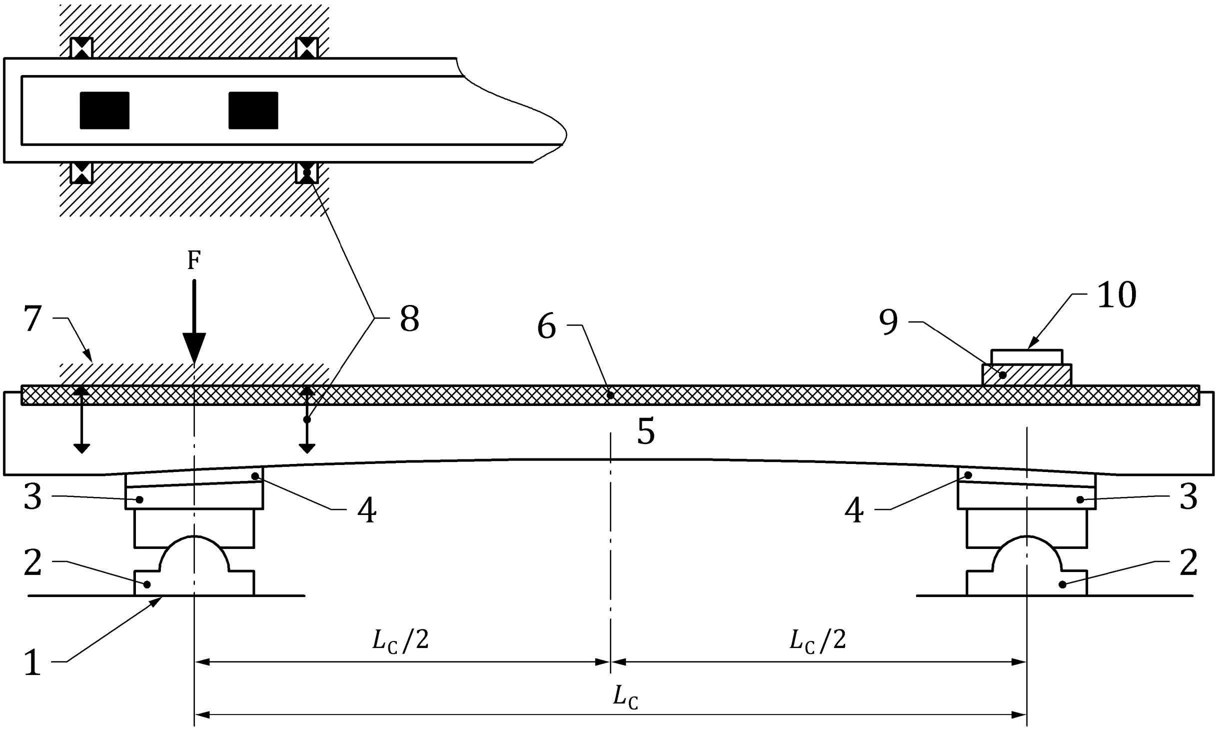
The instruments shall be capable of measuring the vertical displacement of the surface of the test pad as follows:

— for USP with a declared $C_{stat} \leq 0{,}2$ N/mm^3 displacement measurement within ± 0,02 mm;

— for USP with a declared $C_{stat} > 0{,}2$ N/mm^3 displacement measurement within ± 0,01 mm.

K.2.2.7 Force measuring instruments complying with EN ISO 7500-1, class 2 over the required range of force.

K.2.2.8 Recording equipment: equipment to make a digital recording and printout of the displacement and applied force.



Key

1 non-deformable support

2 articulated support (see Annex A for the details of EN 13230-2:2016 for sleepers or EN 13230-4:2016 for bearers)

3 tapered packing (see Annex A for the details of EN 13230-2:2016 for sleepers or EN 13230-4:2016 for bearers) if necessary

4 rail pads

5 concrete sleeper or bearer with USP

6 USP

7 GBP (geometric ballast plate) (see Annex A) fixed to actuator in contact with the sleeper or bearer

8 location of measurements of displacement between GBP and Sleeper

9 resilient pad (see Annex A for the details of EN 13230-2:2016 for sleepers or EN 13230-4:2016 for bearers)

10 bar fixing maintained by two threaded rods M24 with nuts tightened between 10 Nm and 15 Nm

Figure K.1 — Test arrangement

K.2.3 Procedure

The flatness of test area (cross width) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge. The maximum deviation shall be less than 2 mm in order to accept the sleeper head for bedding modulus test.

All components (sleeper with USP, GBP, rail pad, slope taking-up wedge and articulated support) shall be at a temperature of (23 ± 5) °C prior to starting the test. Place the test set-up in the following sequence: flat rigid horizontal base, articulated support, slope taking-up wedge, standard under rail pad defined by the customer, Sleeper with USP, GBP fixed to actuator (where the centre of the plate coincides with the theoretical crossing point between the sleeper centre line and the rail centre line with a tolerance of position ± 3 mm) as shown in Figure K.1.

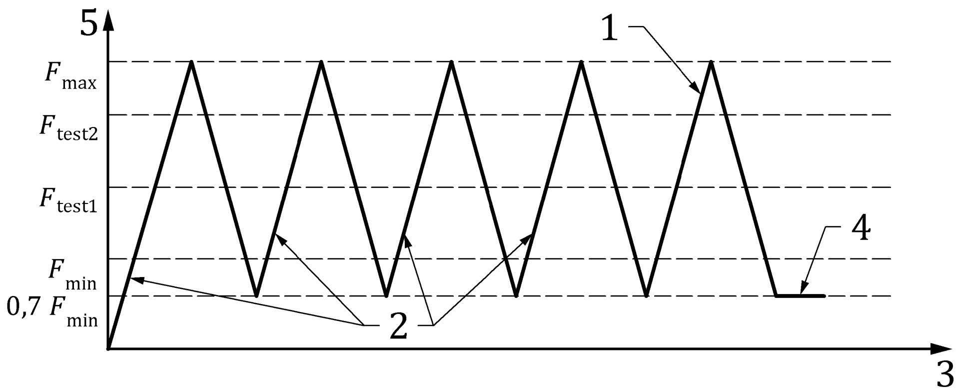
Locate four independent instruments to measure the displacement between the GBP and the sleeper as shown in Figure K.1. The other extremity of the sleeper is maintained as shown in Figure K.1. If the displacement measured by any of the instruments differs from the average displacement by ≥ 20 % of the maximum displacement, repeat the load cycle after at least (60 ± 5) s ensuring that the force is applied centrally to the pad.

Table K.1 — Pressures for measurements of static and low frequency dynamic stiffness and bedding modulus

Track category	p_{min} N/mm²	p_{test1} N/mm²	p_{test2} N/mm²	p_{max} N/mm²
TC1	0,01	0,06	0,12	0,15
TC2		0,08	0,16	0,20
TC3		0,10	0,20	0,25
TC4		0,14	0,28	0,35

Apply a vertical force of ($F_{max} = p_{max} \cdot$ A) through a spherical seating in the actuator (where the centre of GBP coincides with axe of load), as specified in Table K.1. Then reduce the force to 0,7 × F_{min} ($F_{min} = p_{min} \cdot A$ as specified in Table K.1) and repeat this cycle of loading and unloading three times more with a rate of pressure application (0,01 ± 0,001) N/mm²·s. Maintain the applied force (0,7 F_{min}), then record the displacement while increasing the applied force to F_{max} (see Figure K.2).

If a dynamic bedding modulus is measured after the static bedding modulus test, the force is maintained to 0,7 × F_{min}.



Key

1 5th loading: temporal laps to record the displacement while increasing the applied force to F_{max}

2 first four load cycles preconditioning

3 time

4 if a dynamic bedding modulus is measured after the static bedding modulus test, the force is maintained to 0,7 × F_{min}

5 load

Figure K.2 — Load cycle graph

Calculate the static stiffness and static bedding modulus of the fifth load cycle from the following formulae:

$$k_{\text{stat}} = \frac{F_{\text{test1}} - F_{\text{min}}}{d_{\text{test1}} - d_{\text{min}}} \tag{K.1}$$

$$C_{\text{stat}} = \frac{F_{\text{test1}} - F_{\text{min}}}{\left(d_{\text{test1}} - d_{\text{min}}\right) \cdot A} \tag{K.2}$$

where

F_{test1} = $p_{\text{test1}} \cdot A$, as specified in Table K.1

F_{min} = $p_{\text{min}} \cdot A$, as specified in Table K.1

d_{min} is the average displacement of all sensors when the applied force is increased from F_{min}

d_{test1} is the average displacement of all sensors when the applied force is increased from F_{test1}

A is the projected area between USP with GBP

$$k_{\text{tend}} = \frac{F_{\text{test2}} - F_{\text{min}}}{d_{\text{test2}} - d_{\text{min}}} \tag{K.3}$$

$$C_{\text{tend}} = \frac{F_{\text{test2}} - F_{\text{min}}}{\left(d_{\text{test2}} - d_{\text{min}}\right) \cdot A} \tag{K.4}$$

where

the definitions are the same ones as above, except for F_{test2} and d_{test2}:

F_{test2} = $p_{\text{test2}} \cdot A$, as specified in Table K.1

d_{test2} is the average displacement of all sensors when the applied force is increased from F_{test2}

K.2.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) load deflection curve (if demanded by purchaser);

g) value of A;

h) values of F_{min}, F_{max}, F_{test1}, F_{test2}, d_{min}, d_{test1} and d_{test2};

i) static stiffness of each USP tested;

j) static bedding modulus of each USP tested;

k) planarity of USP in contact with GBP.

K.3 Low frequency dynamic test procedure

K.3.1 Principle

This method is valid for one frequency in the range (2 to 30) Hz.

A cyclic force is applied, normal to the test pad of the sleeper, through an actuator at a single specified frequency or, if a general value of low frequency dynamic stiffness is required, at three constant frequencies. The resulting maximum and minimum displacements of the surface of the pad are measured at the maximum and minimum forces.

K.3.2 Apparatus

The following equipment used for the static test is also used in this test:

a) controlled temperature test environment (see K.2.2.1);

b) GBP (geometric ballast plate) (see K.2.2.2);

c) articulated support (see K.2.2.3) and tapered packing (see K.2.2.4).

K.3.2.1 **Actuator** capable of applying a force of up to 0,44 × F_{max} at the required test frequencies.

NOTE Typically the maximum force is 25 kN.

K.3.2.2 **Displacement measuring instruments.**

In accordance with K.2.2.6.

K.3.2.3 **Force measuring instruments** complying with EN ISO 7500-1, class 2 over the required range of force and capable of measurement at a minimum of 20 times per cycle.

K.3.2.4 **Recording equipment:** equipment to make a digital recording and print out of the displacement and applied force at the required test frequencies with a sampling frequency of at least 20 times the loading frequency.

K.3.3 Procedure

The flatness of test area (cross width) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge. The maximum deviation shall be less than 2 mm in order to accept the sleeper head for bedding modulus test.

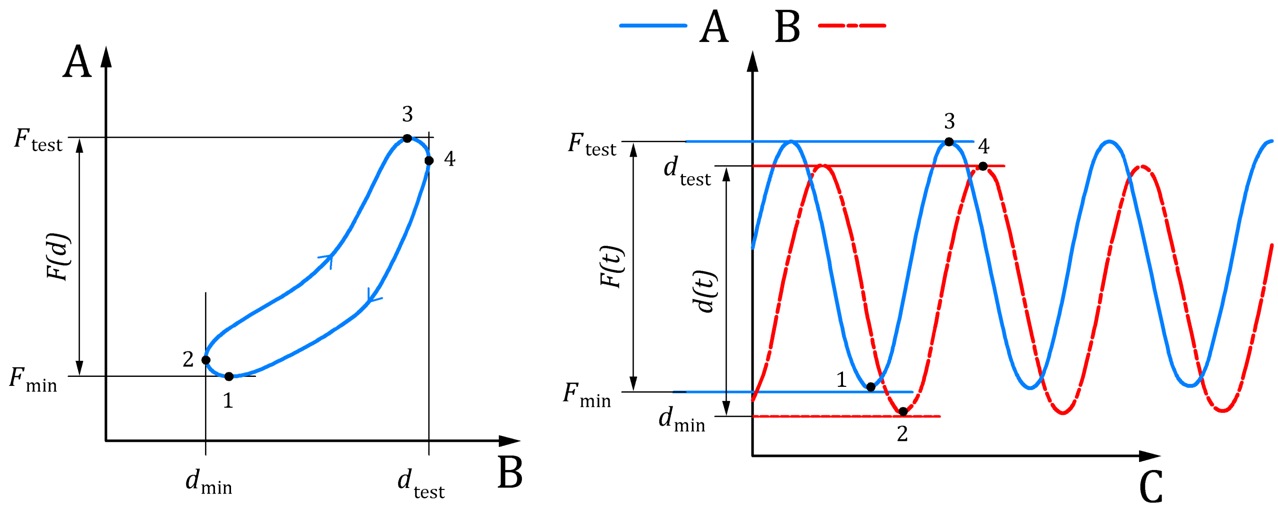
All components (sleeper with USP, GBP, rail pad, slope taking-up wedge and articulated support) shall be at a temperature of (23 ± 5) °C prior to starting the test. Place the test set-up in the following sequence: flat rigid horizontal base, articulated support, slope taking-up wedge, standard under rail pad defined by the customer, Sleeper with USP, GBP fixed to actuator (where the centre of the plate coincides with the theoretical crossing point between the sleeper centre line and the rail centre line with a tolerance of position ± 3 mm) as shown in Figure K.1.

Locate four independent instruments to measure the displacement between the GBP and the sleeper as shown in Figure K.1. The other extremity of the sleeper is maintained as shown in Figure K.1. If the displacement measured by any of the instruments differs from the average displacement by ≥ 20 % of the maximum displacement, repeat the load cycle after at least (60 ± 5) s ensuring that the force is applied centrally to the pad.

If the dynamic bedding modulus test is done after static bedding modulus test, then the dynamic bedding modulus test shall be done within (60 ± 5) s after the static bedding modulus test with a constant load of (0,7 × F_{min} with $F_{min} = p_{min} \cdot A$ as specified in Table K.1).

If another dynamic bedding modulus test is done after a previous one dynamic bedding modulus test, then the following dynamic bedding modulus test shall be done within (60 ± 5) s after the previous one dynamic bedding modulus test with a constant load of ($F_{min} = p_{min} \cdot A$ as specified in Table K.1).

Apply a cyclic force of F_{min} (= $p_{min} \cdot A$) to F_{test} (= $p_{test1} \cdot A$) from Table K.1 at the specified frequency ± 1 Hz for 100 cycles (with 50 cycles maximum in order that the actuator applies the force amplitude demanded) or 10 s for frequencies > 10 Hz (with 5 s maximum in order that the actuator applies the force amplitude demanded). Then record F_{min}, F_{test}, d_{min}, d_{test} for each of these cycles (see Figure K.3).



Key

A force

B displacement

C time

1 F_{min}

2 d_{min}

3 F_{test}

4 d_{test}

Figure K.3 — Low frequency dynamic curves

Calculate the low frequency dynamic stiffness and low frequencies bedding modulus for 10 cycles recorded for each test frequency from the following formula:

$$k_{dyn} = \frac{1}{10} \cdot \sum_{i=1}^{10} \frac{F_{test,i} - F_{min,i}}{d_{test,i} - d_{min,i}} \quad \text{(K.5)}$$

$$C_{dyn} = \frac{k_{dyn}}{A} \quad \text{(K.6)}$$

$$k_{dyn} = \frac{C_{dyn}}{C_{stat}} \quad \text{(K.7)}$$

where

F_{test} = $p_{test1} \cdot A$, as specified in Table K.1

F_{min} = $p_{min} \cdot A$, as specified in Table K.1

d_{min} is the average minimum displacement of all sensors

d_{test} is the average maximum displacement of all sensors

A projected area between USP with GBP

K.3.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) mean load deflection curves;

g) value of A;

h) values of F_{min}, F_{test}, d_{min} and d_{test};

i) low frequency dynamic stiffness of each USP tested;

j) low frequency dynamic bedding modulus of each USP tested;

k) rigidification coefficient of each USP tested;

l) frequency of the test;

m) planarity of USP in contact with GBP.

Annex L
(informative)

Fatigue test on USP on sleeper

L.1 Principle

A cyclic force is applied normal to the test USP with ballast and the bedding modulus is measured before and after fatigue test with USP on sleeper.

L.2 Apparatus

L.2.1 Machine type Vibrogir: machine which applies:

a) a static preload F_{pre} between 48 kN and 116 kN:

1) by the mass of 2 rails (between 11 m and 12 m) (see key (4) in Figure L.1);

2) by the mass of dynamic load system (see key (6) in Figure L.1);

3) by the mass of the tested sleeper with USP (see key (2) in Figure L.1);

4) by the sag of 2 rails (see key (8) in Figure L.1).

A calibration of static preload shall be performed for the first use of the rails, and every 5 years.

NOTE The static preload is the sum of four points above.

$$F_{sag} = \frac{48 \cdot E \cdot I \cdot Sag}{L^3}$$

where

- F_{sag} is the static preload applied by the sag of 2 rails (kN)
- E is Young's Modulus of the rail (kN/m²)
- I is the vertical inertia of the 2 rails (m⁴),
- Sag is the difference in height of the rails between the heavy mass (at the ends) and the sleeper (in the centre of the rails) (m) (see key (8) in Figure L.1)
- L is the support length of sag of 2 rails (m)

EXAMPLES

Example of calculation of static preload $F_{pre} = F_{sag} + F_{mass}$ = 56,14 kN + 23,8 kN = 79,94 kN.

Example of calculation of static preload applied by the sag of 2 rails (F_{sag}): for $E = 210 \cdot 10^6$ kN/m², $I = 6{,}0766 \cdot 10^{-5}$ m⁴ (Inertia of 2 rails 60E1), Sag = 0,122 m, L = 11 m, so F_{sag} = 56,14 kN.

Example of calculation of static preload applied by the mass of 2 rails, by the mass of dynamic load system and by the mass of the tested sleeper with USP (F_{mass}): for the mass of 2 rails = 1 325 kg (2 rails 60E1 of 11 m), the mass of dynamic load system = 820 kg, the mass of the tested sleeper with USP = 280 kg and g = 0,009 81 kN/kg, so F_{mass} = 2 425 kg × 0,009 81 N/kg = 23,8 kN.

b) a dynamic load F_{test}:

By the dynamic load system (see key (6) in Figure L.1) who applies a cyclic force (between ± 8 kN and ± 27 kN) and for a frequency between 30 Hz and 52 Hz.

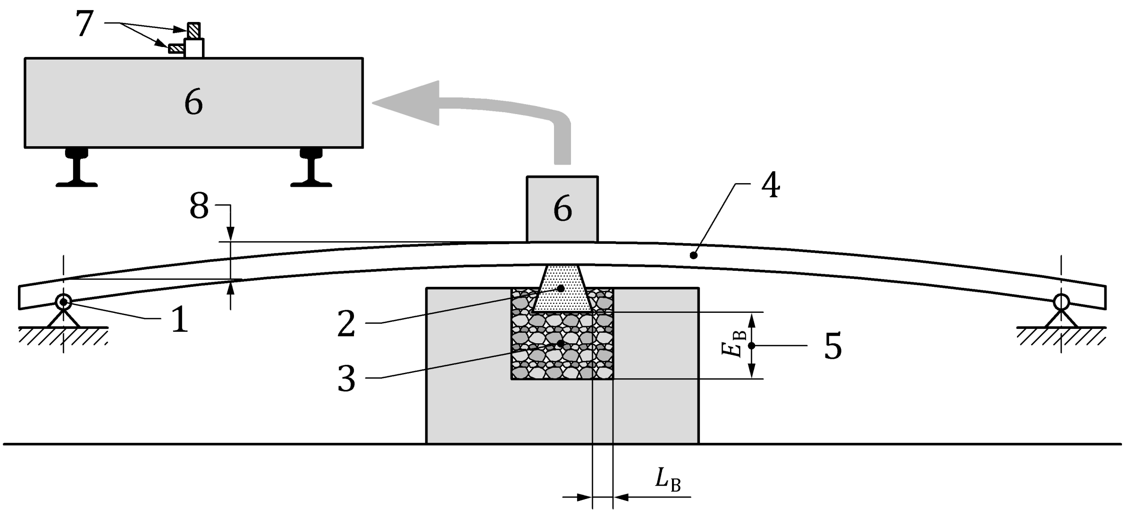
The calibration of the load of every eccentrically loaded motor shall be performed for the first use and every 5 years.

During the test, the eccentric mass shall be adjusted according to this calibration.

L.2.2 **Ballast** according to EN 13450, with a LA_{RB} 14 or less and M_{DE} RB 8 or less.

The ballast shall be new and shall not have been previously used for another test.

L.2.3 **Rail** for the test system, according to the EN 13674 series and not less R260 minimum.



Key

1 Fix points are fixed at the ends of rails (4) in order to exert the preload on the sleeper (2) and should be adjustable the height in order to adjust the sag (8) (example: fix points is a heavy mass of 4,5 t and the adjustment of the height of heavy mass is made with shims)

2 Tested sleeper with USP

3 Ballast with $L_B \geq 200$ mm and $E_B \geq 200$ mm

4 Two rails (length between 11 m and 12 m). The rail profile corresponds to the fastening system of the sleeper

5 Ballast box minimum dimensions [(length of sleeper + 0,6 m) x (width of sleeper + 0,6 m) x (thickness of sleeper + 0,3 m)]

6 Girder: dynamic load system connected by rigid clamping the tested sleeper with USP (2) and the two rails (4)

7 Measurement of vertical and horizontal acceleration of dynamic load system in the centre of the girder (6)

8 Sag: difference in height of the rails between the fix points (1) and the sleeper (2)

Figure L.1 — Test arrangement

L.3 Procedure

Before the fatigue test with USP applied on sleeper, the following information is taken:

— the USP shall be visually inspected for damage (perforation, cracking or other damage) as a result of the installation of the USP on the concrete sleeper, during transportation or handling;

— the static and low frequency dynamic bedding modulus at 5 Hz of one side of the sleeper with USP are measured according to Annex K;

— the flatness of USP is measured. The flatness of test area (cross width) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge;

— the mass of sleeper with USP and fasteners is measured.

Place the test set-up in the following sequence: dynamic load system, two rails (rigid connection between the dynamic load system, the two rails and the sleeper), sleeper with USP, standard rail pad defined by the customer, ballast as shown in Figure L.1.

Table L.1 — Static and dynamic loads ($F_{pre} \pm F_{test}$) for fatigue test of USP on sleeper

Track category	($F_{pre} \pm F_{test}$) kN			
	$C_{dyn,5Hz} \leq 0,04$ N/mm³	0,04 N/mm³ < $C_{dyn,5Hz} \leq 0,15$ N/mm³	0,15 N/mm³ < $C_{dyn,5Hz} \leq 0,25$ N/mm³	$C_{dyn,5Hz} > 0,25$ N/mm³
TC1 and TC2	48 kN ± 12 kN	48 kN ± 12 kN	64 kN ± 16 kN	64 kN ± 16 kN
TC3	48 kN ± 12 kN	64 kN ± 16 kN	80 kN ± 20 kN	80 kN ± 20 kN
TC4	64 kN ± 16 kN	85 kN ± 21 kN	96 kN ± 24 kN	116 kN ± 24 kN

For the starting of test or after a corrected operation of sag (see key (8) of Figure L.1 and the note "Correction method of the sag of one rail"), the static preload (F_{pre} ± 10 %) (see L.2.1 a) for calculation) is applied on the tested sleeper in function of Table L.1 and the difference between the sag of the two rails is ≤ 10 mm.

The acceleration and the frequency are measured during the test (minimum every 6 million cycles).

Correction method of the sag of one rail (side A of the sleeper) against the other rail (side B of the sleeper):

— Step 1 To jack the rail (in order to lift the side A of the sleeper) up of a few centimetres above of the desired sag.

— Step 2 To pack with a crowbar the ballast near the side A of the sleeper.

— Step 3 To withdraw the jacks.

— Step 4 To control the sag of the side A of the sleeper. If the difference between the sag of side A and of side B is > 10 mm, to go back to Step 1.

— Step 5 To prop up with adjusting the fix point (example: shim under the 2 heavy mass) in order to obtain the desired sag for the two rails.

— Step 6 To control the sag of the two sides. If the measured sags give a static preload of F_{pre} ± 10 %, to go back to Step 5.

Apply a cyclic force for 36 million cycles:

— during the first 24 h, the dynamic load is half of the dynamic load ($\pm 1/2 \cdot F_{test}$) of Table L.1 around F_{pre},

— after the dynamic load is value F_{test} of Table L.1 around F_{pre}, at the maximum frequency between 30 Hz and 52 Hz in order that the absolute vertical acceleration of girder is ≤ 3g.

In order to limit the temperature of sample (sleeper and USP), during 30 min, the cyclic force is functioned 20 min and stopped 10 min.

Between 1 week (minimum) and 2 weeks (maximum) after the end of the fatigue test with USP applied on sleeper, the following information is taken (during this period, the USP is without load and the top of concrete sleeper is placed USP bottom up):

— the pad shall be visually inspected in order to look for evidence of damage (assessment of evidence of perforation, cracking or other damage);

— the static and low frequency dynamic bedding modulus at 5 Hz are measured according to Annex K;

— the flatness of USP is measured. The flatness of test area (cross width) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge;

— the mass of sleeper with USP and fasteners is measured.

Calculate the variation of bedding modulus and of mass of sleeper before and after the fatigue test of USP on sleeper:

$$\Delta C_{\text{stat}} = \frac{\Delta C_{\text{stat,af}} - \Delta C_{\text{stat,be}}}{\Delta C_{\text{stat,be}}} \times 100\ [\%] \qquad \text{(L.1)}$$

$$\Delta C_{\text{tend}} = \frac{\Delta C_{\text{tend,af}} - \Delta C_{\text{tend,be}}}{\Delta C_{\text{tend,be}}} \times 100\ [\%] \qquad \text{(L.2)}$$

$$\Delta C_{\text{dyn,5Hz}} = \frac{\Delta C_{\text{dyn, 5Hz,af}} - \Delta C_{\text{dyn, 5Hz,be}}}{\Delta C_{\text{dyn, 5Hz,be}}} \times 100\ [\%] \qquad \text{(L.3)}$$

$$\Delta m = \frac{m_{\text{af}} - m_{\text{be}}}{m_{\text{be}}} \times 100\ [\%] \qquad \text{(L.4)}$$

L.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) value of F_{pre} and F_{test};

g) results of static and low frequency dynamic bedding modulus at 5 Hz before and after the test;

h) results of flatness before and after the test of each USP tested;

i) variations of bedding modulus of each USP tested;

j) results of visual inspection before and after the test with photos;

k) variation of mass before and after the test of each USP tested;

l) measured accelerations and frequencies during the test.

Annex M
(informative)

Alternative fatigue test on USP on sleeper

M.1 Principle

A cyclic force is applied normal to the test USP in ballast and the bedding modulus is measured before and after fatigue test with USP on sleeper.

M.2 Apparatus

M.2.1 Controlled temperature test environment: the area of the laboratory where the test is conducted, maintained at (23 ± 5) °C.

M.2.2 Actuator capable of applying a force of 1,1 F_{max}.

M.2.3 Force measuring instruments complying with EN ISO 7500-1, class 2 over the required range of force.

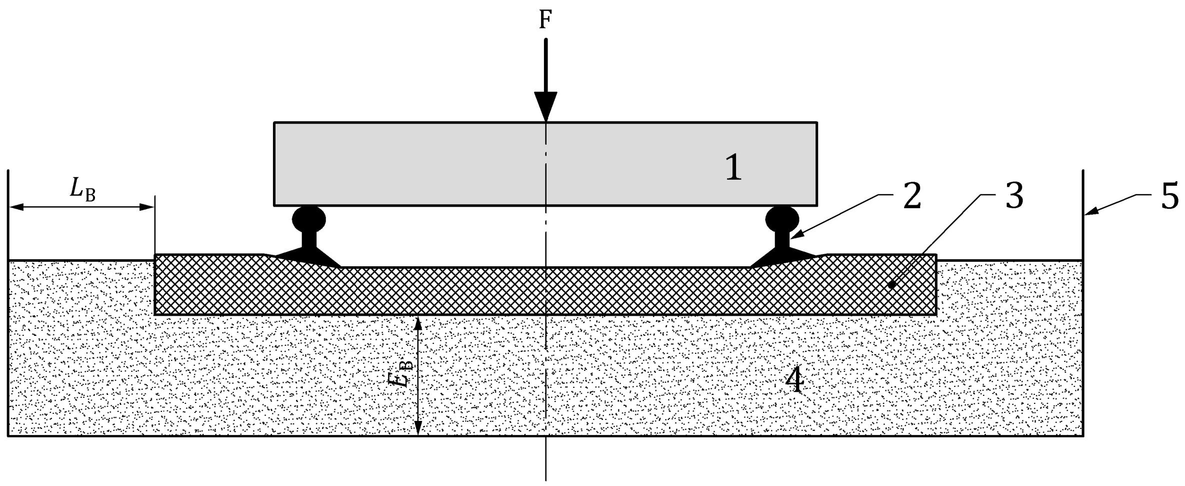
M.2.4 Recording equipment to make a digital recording and printout of applied force.

M.2.5 Ballast according to EN 13450, with a LA_{RB} 14 or less and $M_{DE}RB$ 8 or less.

The ballast shall be new and shall not be used for another test before.

M.2.6 Rail for the test system, according to the EN 13674 series and minimum length of 500 mm.

M.2.7 Girder: rigid element with a length ≥ (sleeper gauge + 200 mm) and a width ≥ 200 mm, in order to transmit the force of actuator in order to distribute the force of actuator towards the two rails.



Key

1 girder connected by rigid clamping with the force actuator and with the two rails

2 two rails (length minimum 0,5 m) and the rail profile corresponds of the fastening system of the sleeper

3 tested sleeper with USP

4 ballast with $L_B \geq 200$ mm and $E_B \geq (250 \pm 50)$ mm

5 ballast box (non-deformable)

Figure M.1 — Test arrangement

M.3 Procedure

Before the fatigue test with USP applied on sleeper, the following information is taken:

— the USP shall be visually inspected for damage (perforation, cracking or other damage) as a result of the installation of the USP on the concrete sleeper, during transportation or handling;

— the static and low frequency dynamic bedding modulus at 5 Hz of one side of the sleeper with USP are measured according to Annex K;

— the flatness of USP is measured; the flatness of test area (cross width) is measured with a straight ruler of 300 mm (minimum length) and by means of a feeler gauge;

— the mass of sleeper with USP and fasteners is measured.

Place the test set-up in the following sequence: rigid girder, two rails (rigid connection between the dynamic load system, the two rails and the sleeper), sleeper with USP, standard rail pad defined by the customer, ballast as shown in Figure M.1. The minimum test load F_{min} is 5 kN.

Table M.1 —Maximum load for the alternative test procedure for the fatigue test with of USP on sleeper (F_{max})

Track category	F_{max} (kN)			
	$C_{dyn,5Hz} \leq 0,04$ N/mm³	0,04 N/mm³ < $C_{dyn,5Hz} \leq 0,15$ N/mm³	0,15 N/mm³ < $C_{dyn,5Hz} \leq 0,25$ N/mm³	$C_{dyn,5Hz} > 0,25$ N/mm³
TC1 and TC2	60 kN	60 kN	80 kN	80 kN
TC3	60 kN	80 kN	100 kN	100 kN
TC4	80 kN	106 kN	120 kN	140 kN

Apply a sinusoidal force for 8 million cycles:

— during the first 2 000 cycles, the dynamic load is between the dynamic load (F_{min}) and (1/2 F_{max}) of Table M.1 at the maximum frequency 5 Hz;

— during the 2nd 2 000 cycles, the dynamic load is between the dynamic load (F_{min}) and (F_{max}) of Table M.1 at the maximum frequency 5 Hz;

— after 4 000 cycles, the dynamic load is between the dynamic load (F_{min}) and (F_{max}) of Table M.1 at the maximum frequency 10 Hz (reduced the frequency or stopped when the temperature of the sample exceeds 40 °C).

Between 1 week (minimum) and 2 weeks (maximum) after the end of the fatigue test with USP on sleeper, the following information is taken (during this period, the USP is without load and is the top of concrete sleeper):

— the USP shall be visually inspected in order to look for evidence of damage (assessment of evidence of perforation, cracking or other damage);

— the static and low frequency dynamic bedding modulus at 5 Hz are measured according to Annex K;

— the flatness of USP is measured; the flatness of test area is measured with a straight ruler of 300 mm and by means of a feeler gauge;

— the mass of sleeper with USP and fasteners is measured.

Calculate the variation of bedding modulus and of mass of sleeper before and after the alternative fatigue test of USP on sleeper:

$$\Delta C_{\text{stat}} = \frac{\Delta C_{\text{stat,af}} - \Delta C_{\text{stat,be}}}{\Delta C_{\text{stat,be}}} \times 100\ [\%] \tag{M.1}$$

$$\Delta C_{\text{tend}} = \frac{\Delta C_{\text{tend,af}} - \Delta C_{\text{tend,be}}}{\Delta C_{\text{tend,be}}} \times 100\ [\%] \tag{M.2}$$

$$\Delta C_{\text{dyn,5Hz}} = \frac{\Delta C_{\text{dyn, 5Hz,af}} - \Delta C_{\text{dyn, 5Hz,be}}}{\Delta C_{\text{dyn, 5Hz,be}}} \times 100\ [\%] \tag{M.3}$$

$$\Delta m = \frac{m_{\text{af}} - m_{\text{be}}}{m_{\text{be}}} \times 100\ [\%] \tag{M.4}$$

M.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) static and low frequency dynamic bedding modulus of the USP tested before and after the fatigue test of each USP tested;

g) variations of static and low frequency dynamic bedding modulus of each USP tested;

h) mass of the sleeper tested before and after the fatigue test of each USP tested;

i) variation of mass of the sleeper tested before and after the fatigue test of each USP tested;

j) results of visual inspection before and after the test with photos.

Annex N
(informative)

Effect of severe environmental conditions on USP on concrete block

N.1 Principle

The bedding modulus is measured before and after a climatic sequence.

N.2 Apparatus

N.2.1 Climatic chamber that shall be large enough to accept a concrete block according to Annex B with a temperature range between −15 °C and 40 °C.

The climatic chamber shall be calibrated for an accuracy of ± 3 °C for the temperatures −15 °C and 40 °C.

N.2.2 USP on concrete block; see Annex B.

N.3 Procedure

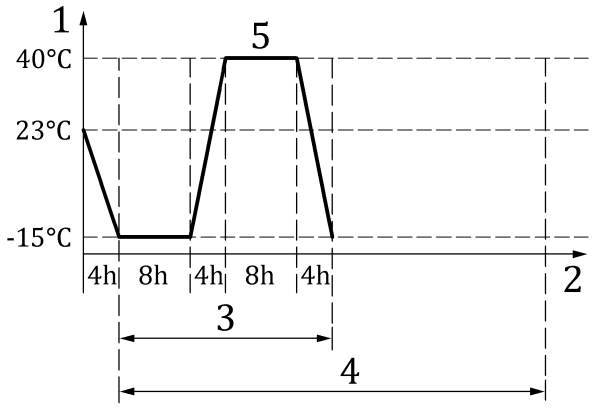
Before the effect of severe environmental conditions of USP on concrete block, the following information is taken:

— the USP shall be visually inspected for damage (perforation, cracking or other damage) as a result of the installation of the USP on the concrete block, during transportation or handling. The USP shall be free of damage;

— the static and lower frequency dynamic bedding modulus at 5 Hz are measured according to Annex C.

The concrete block with USP is immersed in water during 24 h with temperature (23 ± 5) °C.

Then it is removed from the water and placed in a climatic chamber for 7 cycles of 24 h of the following graph (see Figure N.1).



Key

1 temperatures of the climatic chamber in °C (Axis Y)

2 time in hours (Axis X)

3 1 cycle of 24 h

4 7 times the cycle defined by the key 3

5 80 % HR (relative humidity) during the 8 h period of 40 °C

Figure N.1 — Climatic cycle

After the 7 cycles, the sample tested shall be kept in a temperature of (23 ± 5) °C.

Between 1 week (minimum) and 2 weeks (maximum) after the end of the effect of severe environmental conditions of USP on concrete block, the following information is taken (during this period, the USP is without load and is on the top of concrete sleeper):

— the USP shall be visually inspected in order to look for evidence of damage (assessment of evidence of perforation, cracking or other damage);

— the static and low frequency dynamic bedding modulus at 5 Hz are measured according to Annex C;

— pull-out test after bedding modulus test (minimum 3 pull-out tests, see Figure N.2) analogous to Annex E.

Dimensions in millimetres

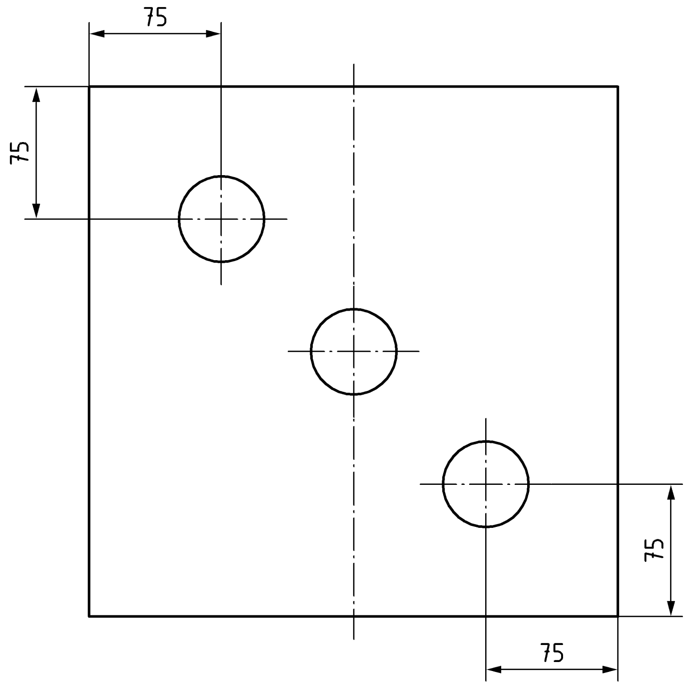


Figure N.2 — Location of 3 pull-out tests on USP

Calculate the variation of static and low frequency dynamic bedding modulus:

$$\Delta C_{\text{stat}} = \frac{\Delta C_{\text{stat,af}} - \Delta C_{\text{stat,be}}}{\Delta C_{\text{stat,be}}} \times 100 \, [\%] \quad \text{(N.1)}$$

$$\Delta C_{\text{tend}} = \frac{\Delta C_{\text{tend,af}} - \Delta C_{\text{tend,be}}}{\Delta C_{\text{tend,be}}} \times 100 \, [\%] \quad \text{(N.2)}$$

$$\Delta C_{\text{dyn,5Hz}} = \frac{\Delta C_{\text{dyn, 5Hz,af}} - \Delta C_{\text{dyn, 5Hz,be}}}{\Delta C_{\text{dyn, 5Hz,be}}} \times 100 \, [\%] \quad \text{(N.3)}$$

N.4 Test report

The test report shall include also at least the following information:

a) number, name and date of issue of this standard;

b) name and address of the laboratory performing the test;

c) date of test performed;

d) name, designation and description of the test specimens;

e) origin of the test specimens;

f) results of static and low frequency dynamic vertical bedding modulus at 5 Hz before and after the test of each USP tested;

g) results of visual inspection before and after the test with photos;

h) results of the pull-out test.

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK