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**Railway applications — Polymeric  
composite sleepers, bearers and  
transoms —**

**Part 3:  
General requirements**

*Applications ferroviaires — Traverses et supports en matériaux  
composites à matrice polymère —*

*Partie 3: Exigences générales*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 269, *Railway applications*, Subcommittee SC 1, *Infrastructure*.

A list of all parts in the ISO 12856 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

This document is used as the technical basis for transaction between corresponding parties (purchaser – supplier).

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# Railway applications — Polymeric composite sleepers, bearers and transoms —

## Part 3: General requirements

### 1 Scope

This document specifies general requirements of polymeric composite railway sleepers. It is applicable to the sleepers, bearers and transoms to be installed in all tracks (both heavy and urban rail) with or without ballast.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12856-1, *Railway applications — Polymeric composite sleepers, bearers and transoms — Part 1: Material characteristics*

ISO 12856-2, *Railway applications — Polymeric composite sleepers, bearers and transoms — Part 2: Product testing*

### 3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1

##### **purchaser**

body responsible for purchasing the product on the network company's behalf

#### 3.2

##### **supplier**

body responsible for the use of the International Standard in response to the *purchaser's* (3.1) requirement

Note 1 to entry: The supplier is also responsible for requirements which apply to the product of the *manufacturer* (3.3).

#### 3.3

##### **manufacturer**

organization which produces the *sleepers* (3.4), the *bearers* (3.5) and the *transoms* (3.6)

**3.4**

**sleeper**

transverse component of the track which controls the *gauge* (3.29) and transmits loads from the rail to the ballast or other sleeper support

**3.5**

**bearer**

transverse component of switches and crossings which controls the relative geometry of two or more running rails and different pieces of special track work, and transmits loads from the rails to the ballast or other bearer support

**3.6**

**transom**

transverse component of track on bridges with open deck which controls the *gauge* (3.29) and transmits loads from the rail to the bridge structure

**3.7**

**longitudinal beams for ballastless track on bridges**

longitudinal component of *ballastless track* (3.27) on bridges which supports several *fastening systems* (3.28) for one rail

**3.8**

**bending moment**

moment applied on the polymeric composite *sleeper* (3.4), *bearer* (3.5) or *transom* (3.6) which produces tension and compression in the element

**3.9**

**positive bending moment**

moment which produces tension at the bottom of the polymeric composite *sleeper* (3.4), *bearer* (3.5) or *transom* (3.6)

**3.10**

**negative bending moment**

moment which produces tension at the top of the polymeric composite *sleeper* (3.4), *bearer* (3.5) or *transom* (3.6)

**3.11**

**rail seat**

area on which a running rail rests

**3.12**

**rail seat area**

*rail seat* (3.11) and the immediate area around the *fastening system* (3.28)

**3.13**

**rail seat bending moment**

moment under the centre line of the rail

**3.14**

**centre bending moment**

moment at the centre part of a *monoblock sleeper* (3.15)

**3.15**

**monoblock sleeper**

*sleeper* (3.4) consisting of one element of material

**3.16**

**twin-block sleeper**

*sleeper* (3.4) in which two *blocks* (3.17) are connected by a connecting bar

**3.17****block**

short polymeric composite element which transmits loads from one rail to the ballast or other support

**3.18****test load**

load applied during testing

**3.19****dynamic rail seat load**
 $P_k$ 

characteristic load on a *rail seat* (3.11) of the *sleeper* (3.4) for normal service dynamic loading

Note 1 to entry: Usually the characteristic load corresponds to the mean value plus “n” standard deviations of the dynamic wheel load.

Note 2 to entry: The term “dynamic load” used within this series, with respect to tests, should be interpreted as “cyclic load”.

**3.20****characteristic bending moment**
 $M_k$ 

*bending moment* (3.8) from the *dynamic rail seat load* (3.19)

**3.21****characteristic positive bending moment for rail seat section**
 $M_{k,r,pos}$ 

*positive bending moment* (3.9) at the *rail seat* (3.11) from the *dynamic rail seat load* (3.19)

**3.22****characteristic negative bending moment for rail seat section**
 $M_{k,r,neg}$ 

*negative bending moment* (3.10) at the *rail seat* (3.11) from the *dynamic rail seat load* (3.19)

**3.23****characteristic negative bending moment for centre section**
 $M_{k,c,neg}$ 

*negative bending moment* (3.10) at the centre section from the *dynamic rail seat load* (3.19)

**3.24****characteristic positive bending moment for centre section**
 $M_{k,c,pos}$ 

*positive bending moment* (3.9) at the centre section from the *dynamic rail seat load* (3.19)

**3.25****thermal expansion**

elongation of the *sleeper* (3.4), *bearer* (3.5) or *transom* (3.6) as a result of increasing temperature

**3.26****bedding modulus**

pressure (force per surface area) per unit deflection and measured under a uniaxial load

**3.27****ballastless track**

high fixity track constrained by means other than ballast

**3.28****fastening system**

any device used to secure running rails into chairs or baseplates or directly to *sleepers* (3.4), *bearers* (3.5), *transoms* (3.6) or other rail supports

**3.29**

**gauge**

lateral distance between the running edges of rails in track

**3.30**

**lateral track resistance**

ability of a *sleeper* (3.4) to resist movement, perpendicular to rail, under lateral loading

**3.31**

**conductor rail**

rigid metallic section or rail mounted on insulators to distribute electrical energy to trains

**3.32**

**geometric ballast plate**

**GBP**

rigid steel plate with geometrically structured surface simulating ballast contact

Note 1 to entry: See ISO 12856-2:2020, Annex A.

**3.33**

**flat plate**

**FP**

rigid steel plate with flat surface with dimension 300 mm by 300 mm

**3.34**

**design approval test**

test on a polymeric composite *sleeper* (3.4), *bearer* (3.5) or *transom* (3.6) or part of it to demonstrate compliance with the acceptance criteria

**3.35**

**routine test**

quality control test in terms of regular manufacturing

**4 Symbols**

For the purposes of this document, the symbols and abbreviated terms listed in [Table 1](#) apply.

**Table 1 — Symbols**

Symbol	Description	Unit
$b_1$	Maximum bottom width of the polymeric composite sleeper, bearer or transom.	m
$b_2$	Top width of the polymeric composite sleeper, bearer or transom.	m
$b_3$	Top width of the polymeric composite sleeper, bearer or transom at the axis of the rail seat.	m
$d_{0s}$	Deformation of the sleeper in the strength test under $F_{r0}$ .	mm
$d_{1s}$	Deformation of the sleeper in the strength test under $k_{1s} \times F_{r0}$ .	mm
$d_{2s}$	Deformation of the sleeper in the strength test under $k_{2s} \times F_{r0}$ .	mm
$d_{1s,lim}$	Upper limit for the sleeper deformation in the strength test at exceptional load level.	mm
$d_{2s,lim}$	Upper limit for the sleeper deformation in the strength test at accidental load level.	mm
$F$	Planeness of each rail seat area: with regard to two points 150 mm apart.	—
$F_{c0}$	Positive reference test load at the centre section of the sleeper.	kN
$F_{c0n}$	Negative reference test load at the centre section of the sleeper	kN
$F_{r0}$	Positive reference test load for the rail seat section.	kN
$F_{cB}$	Maximum positive test load at centre of sleeper, bearer or transom.	kN
$F_{cBn}$	Maximum negative test load at centre of sleeper, bearer or transom.	kN

Table 1 (continued)

Symbol	Description	Unit
$F_{c,perm,n}$	Constant load applied for permanent deformation test at the centre section for negative bending moments.	kN
$F_{rB}$	Maximum positive test load at the rail seat section which cannot be increased.	kN
$h$	Depth at any position along the total length of the polymeric composite sleeper, bearer or transom measured in accordance with the quality plan.	m
$k_{1s}$	Coefficient used for calculation of static test load for the exceptional load level. This factor is applied to initial reference test load.	—
$k_{2s}$	Coefficient used for calculation of static test load for the accidental load level. This factor is applied to initial reference test load.	—
$k_3$	Coefficient to be used for calculation of $F_{rB}$ at the end of the fatigue test.	—
$k_{c,dyn1}$	Dynamic low frequency stiffness at the centre section for the positive bending moment in between the loads $0,1 \times F_{c0}$ and $0,5 \times F_{c0}$ .	MN/m
$k_{c,dyn2}$	Dynamic low frequency stiffness at the centre section for the positive bending moment in between the loads $0,1 \times F_{c0}$ and $F_{c0}$ .	MN/m
$k_{c,stat1}$	Static stiffness at the centre section for the positive bending moment in between the loads $0,1 \times F_{c0}$ and $0,5 \times F_{c0}$ .	MN/m
$k_{c,stat2}$	Static stiffness at the centre section for the positive bending moment in between the loads $0,1 \times F_{c0}$ and $F_{c0}$ .	MN/m
$k_{cn,dyn1}$	Dynamic low frequency stiffness at the centre section for the negative bending moment in between the loads $0,1 \times F_{c0n}$ and $0,5 \times F_{c0n}$ .	MN/m
$k_{cn,dyn2}$	Dynamic low frequency stiffness at the centre section for the negative bending moment in between the loads $0,1 \times F_{c0n}$ and $F_{c0n}$ .	MN/m
$k_{cn,stat1}$	Static stiffness at the centre section for the negative bending moment in between the loads $0,1 \times F_{c0n}$ and $0,5 \times F_{c0n}$ .	MN/m
$k_{cn,stat2}$	Static stiffness at the centre section for the negative bending moment in between the loads $0,1 \times F_{c0n}$ and $F_{c0n}$ .	MN/m
$k_{dyn,5Hz}$	Low frequency dynamic stiffness of polymeric composite sleeper or bearer measured with GBP at $(5 \pm 1)$ Hz.	MN/m
$k_{max}$	Static stiffness of polymeric composite sleeper, bearer or transom measured with GBP between $F_{max}$ and $F_{min}$ .	MN/m
$k_{r,dyn1}$	Dynamic low frequency stiffness at the rail seat section in between the loads $0,1 \times F_{r0}$ and $0,5 \times F_{r0}$ .	MN/m
$k_{r,dyn2}$	Dynamic low frequency stiffness at the rail seat section in between the loads $0,1 \times F_{r0}$ and $F_{r0}$ .	MN/m
$k_{r,stat1}$	Static stiffness at the rail seat section in between the loads $0,1 \times F_{r0}$ and $0,5 \times F_{r0}$ .	MN/m
$k_{r,stat2}$	Static stiffness at the rail seat section in between the loads $0,1 \times F_{r0}$ and $F_{r0}$ .	MN/m
$k_{stat}$	Static stiffness of polymeric composite sleeper, bearer or transom measured with GBP between $F_{test}$ and $F_{min}$ .	MN/m
$k_t$	Coefficient used for the degradation during service life of the sleeper.	—
$L$	Overall length of the polymeric composite sleeper, bearer or transom.	m
$L_1$	Distance between the rail fastening gauge points.	m
$L_2$	Position of the rail fastening gauge point with regard to the end of the polymeric composite sleeper, bearer or transom.	m
$L_3$	Total length of reinforced polymeric composite block.	m
$L_c$	Design distance between centre lines of the rail seats.	m
$L_{el}$	Elastic length of the Winkler beam.	m
$L_p$	Design distance between the centre line of the rail seat to the edge of the sleeper at the bottom.	m
$m$	Mass of the sleeper (variation with regard to nominal mass).	kg

Table 1 (continued)

Symbol	Description	Unit
$M_k$	Characteristic bending moment.	kNm
$M_{k,c,neg}$	Characteristic negative bending moment for centre section.	kNm
$M_{k,c,pos}$	Characteristic positive bending moment for centre section.	kNm
$M_{k,r,neg}$	Characteristic negative bending moment for rail seat section.	kNm
$M_{k,r,pos}$	Characteristic positive bending moment for rail seat section.	kNm
$P_k$	Dynamic rail seat load.	kN
$T$	Relative twist between two rail seats (see <a href="#">Annex A</a> ).	°
$\Delta u$	Deformation for permanent deformation test of screw/insert in function of temperature.	mm
$\alpha$	Inclination of the rail seat (see <a href="#">Annex A</a> ).	°
$\alpha_{T,bottom}$	Linear thermal expansion coefficient for the bottom.	K <sup>-1</sup>
$\alpha_{T,top}$	Linear thermal expansion coefficient for the top.	K <sup>-1</sup>
$\lambda$	Lever length of resulting internal forces $P_k/2$ .	m
$\xi$	Position of unit wheel load $Q$ in function of the deflection of rail.	rad
$\eta$	Influence of adjacent axles.	—

## 5 General characteristics

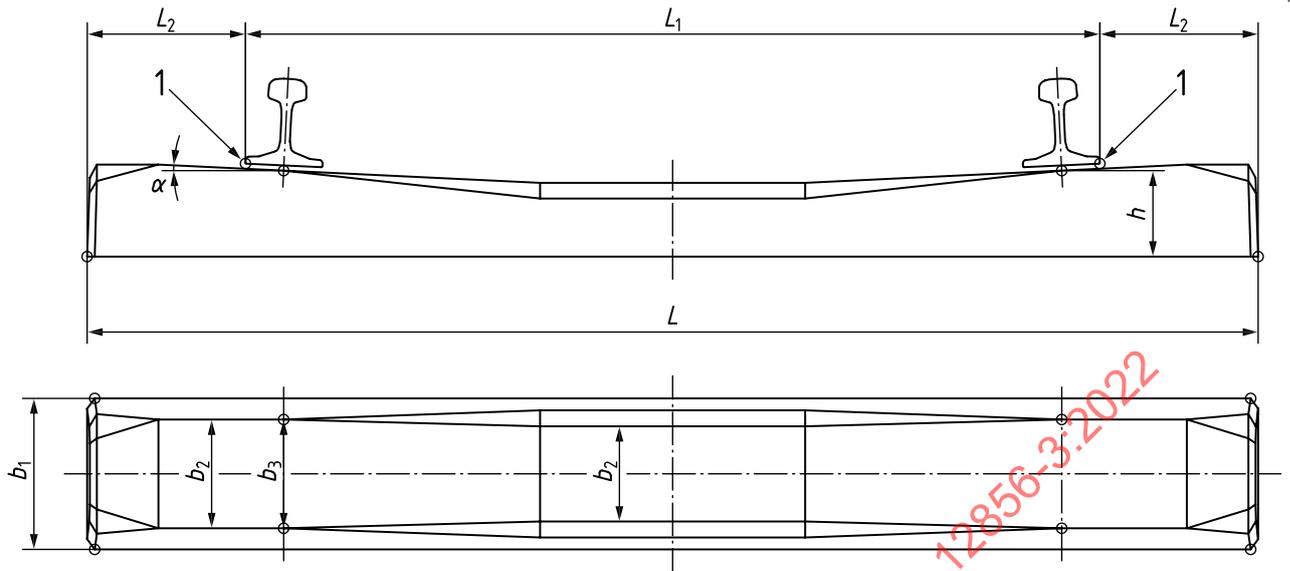
### 5.1 General

The track, including switches and crossings, is an assembly of transverse sleepers, bearers or transoms secured to the rails by means of a fastening system and supported by ballast or other support. It is characterized by the gauge of the track, the rail profile, the inclination of the rails and the spacing of the polymeric composite sleepers, bearers and transoms.

### 5.2 Geometrical design, mass and tolerances

The relevant dimensions of polymeric composite sleepers, bearers and transoms are shown in [Figures 1, 2 and 3](#).

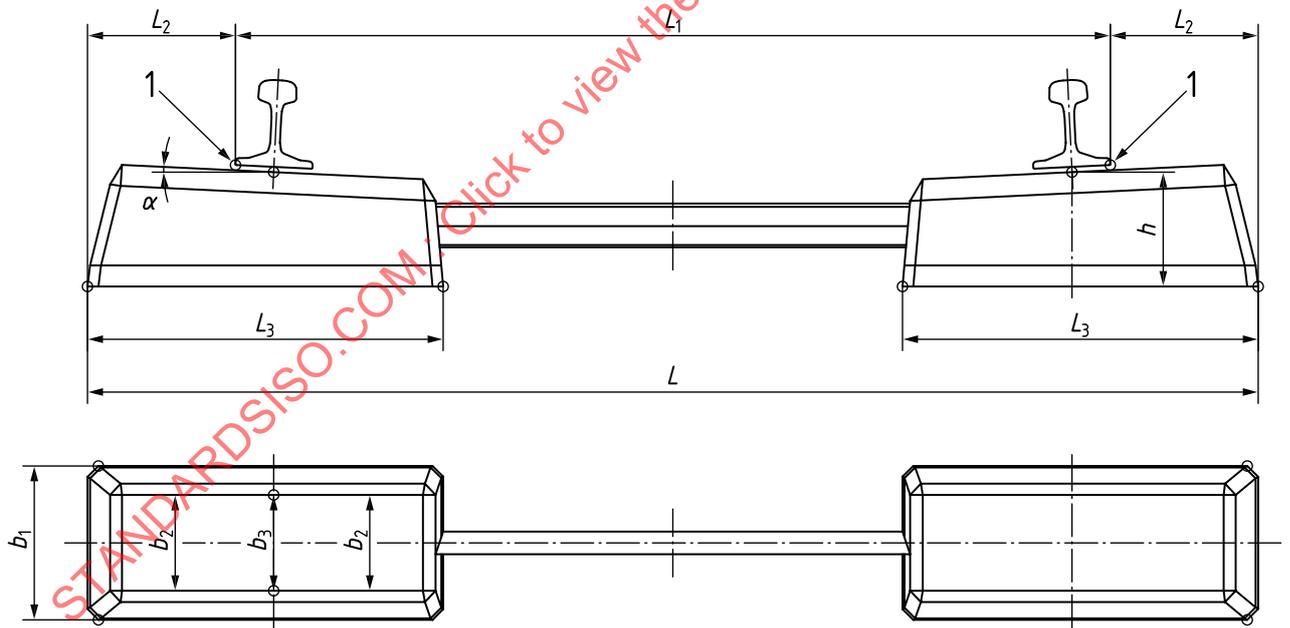
NOTE 1 In case of sleepers with rectangular cross-section over the total length,  $b_3$  is only applied on the rail seat.  $b_1, b_2, b_3$  are all equal and  $\alpha = 0$ .



**Key**

- 1 measurement point
- $L_1$  distance between sleeper gauge points taking into account the fastening system and track gauge

**Figure 1 — Monoblock sleeper**



**Key**

- 1 measurement point
- $L_1$  distance between sleeper gauge points taking into account the fastening system and track gauge

**Figure 2 — Twin-block sleeper**

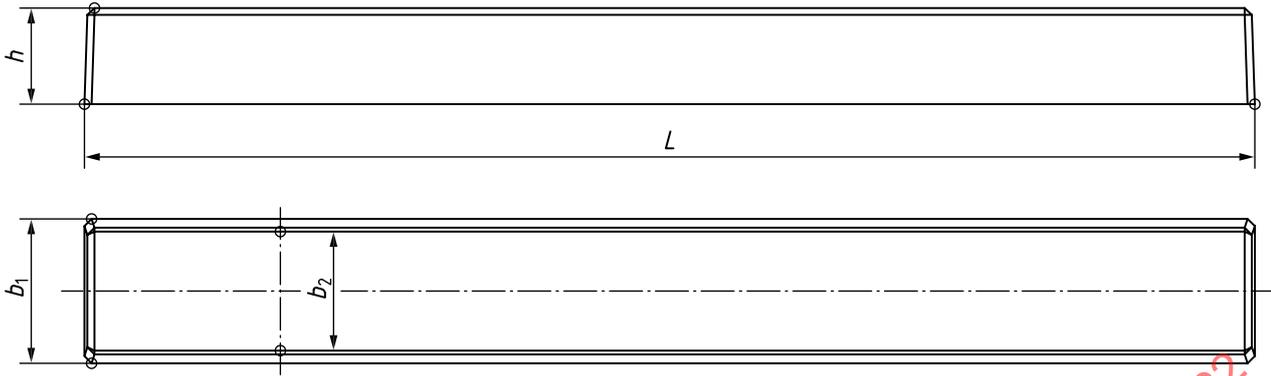


Figure 3 — Sleepers, bearers and transoms

The dimensions of the sleeper, bearer and transom shall be agreed between the purchaser and the supplier.

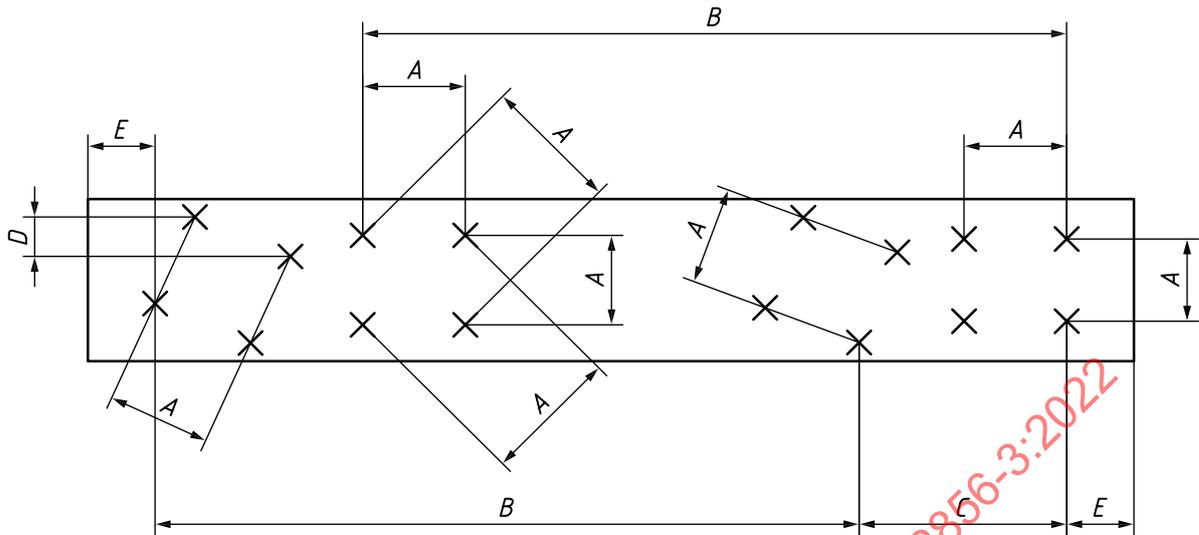
The maximum tolerances specified in Table 2 and below Figure 4 apply to ballasted track and may be varied by the purchaser in the case of special requirements such as dedicated polymeric composite elements for ballastless track or use of a sleeper laying machine, etc.

Table 2 — Maximum tolerances

Symbol	Tolerance
$L$	$\pm 30 \text{ mm}^a$
$b_1$	$\pm 5 \text{ mm}$
$b_2$	$\pm 5 \text{ mm}$
$b_3$	$\pm 5 \text{ mm}$
$h$	$\begin{pmatrix} +10 \\ -3 \end{pmatrix} \text{ mm}$
$L_1$	$\begin{pmatrix} +2 \\ -1 \end{pmatrix} \text{ mm}$
$L_2$	$\pm 8 \text{ mm}$
$L_3$	$\pm 8 \text{ mm}$
$\alpha$	$\pm 0,5^\circ \text{ }^b$
$F$	$2 \text{ mm}^c$
$T$	$0,5^\circ$
$m^d$	$\pm 5 \%$

<sup>a</sup> For installation with a track laying machine, a tolerance of  $\pm 10 \text{ mm}$  is recommended.  
<sup>b</sup> If a baseplate is used, a tolerance of  $\pm 0,25^\circ$  is recommended.  
<sup>c</sup> If a direct fastening (fastening without baseplate) is used, a tolerance of  $1 \text{ mm}$  is recommended.  
<sup>d</sup> The purchaser shall indicate if all or part of the fastening system is included in the mass of the polymeric composite element.

In case of embedded fastening components, the positioning of these components in the sleeper, bearer and transom shall be measured in accordance with Figure 4.



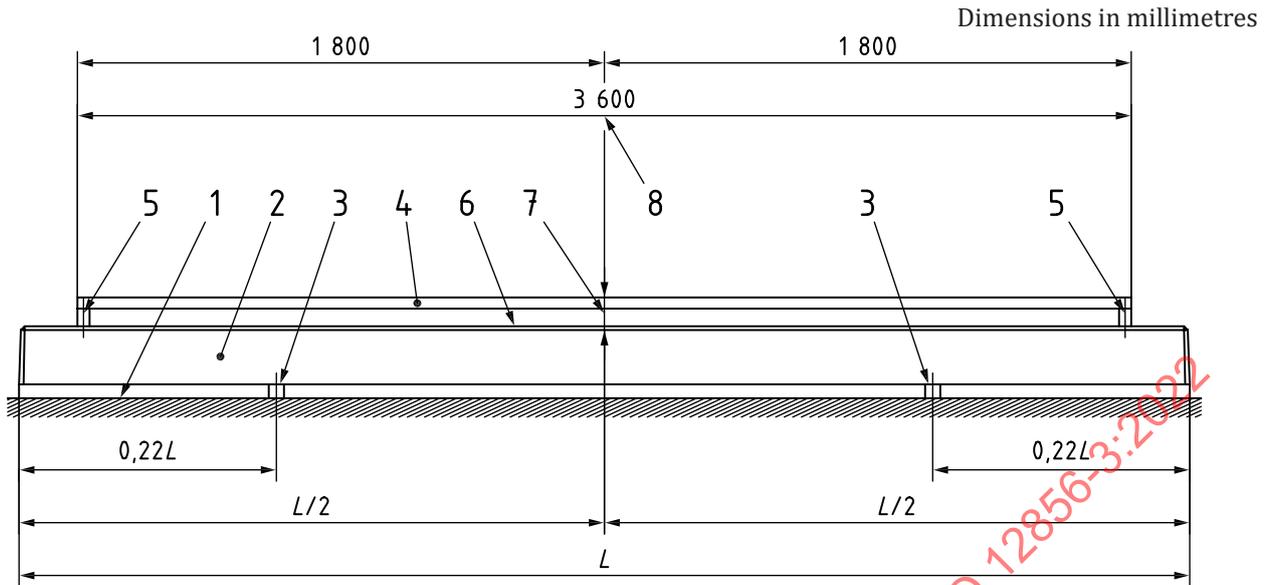
**Figure 4 — Measurement of tolerances on fastening components positioning of bearer**

Tolerance on dimensions A and D (on the same support area):  $\pm 1,0$  mm

Tolerance on dimensions B and C (between two separate supports areas):  $\pm 1,5$  mm

Tolerance between the last cast-in component and the end of the bearer (E):  $\pm 15$  mm

[Figure 5](#) shows the vertical deviation measurement of a bearer.



**Key**

- 1 rigid support
- 2 bearer
- 3 support (50 mm × 50 mm section) across width of bearer
- 4 straight datum
- 5 support across width of bearer
- 6 top surface of bearer
- 7 vertical deviation measurement area
- 8 measurement base

**Figure 5 — Vertical deviation measurement of bearer**

Vertical deviation in both directions of a bearer is measured on a 3,6 m long base as in [Figure 5](#).

Alternative measurement methods may be proposed by the manufacturer and agreed with the purchaser.

For bearers shorter than 4 m and with more than two rail seats, the length of measurement base shall be reduced to  $L - 400$  mm (with  $L$  in mm). Maximum allowed deviation is  $(L - 400) / 500$  (with  $L$  in mm).

Maximum allowed deviation is 7 mm on a 3,6 m base.

For bearer length above 6 m, the maximum allowed deviation is agreed between the supplier and the purchaser.

The design, dimensions and tolerances of the fastening system shall be defined by the purchaser.

The purchaser shall specify the minimum clearances between rail fastening components and reinforcement according to the fastening system to be used, and between reinforcement and connecting bar for twin-block sleepers.

Transportation to the work site and track installation methods can limit the maximum sleeper mass, which has to be determined by the purchaser.

The mass of the sleeper contributes to the longitudinal, lateral and vertical resistance of the track.

The lateral and longitudinal resistance of the sleeper can be measured in the sleeper-in-ballast test or in track.

NOTE 2 A method and principle of test are described in Reference [3].

The vertical resistance of the sleeper in ballasted track is determined by the mass of the sleeper, the resistance in the ballast and, if applicable, the ballast lifted along with the sleeper. If the purchaser requires minimum sleeper mass for track stability, the mass of ballast lifted along with the sleeper may also be considered.

### 5.3 Surface finish

Particular attention shall be paid to the rail seat area, which shall be free of any individual large void. The purchaser shall specify the permissible size, shape and number of voids.

### 5.4 Loading

#### 5.4.1 Loads

The track is subjected to repeated loads in three different directions, generally applied simultaneously:

- a) vertical loads from axle load and service conditions;
- b) transverse loads from guiding forces;
- c) longitudinal loads from acceleration and braking, thermal stresses in continuous welded rail, etc.

Under all loading conditions the track shall retain its geometry including gauge, top, level and alignment.

The characteristic load is calculated by applying a dynamic coefficient to the static wheel load.

The dynamic coefficient takes into account the normal dynamic effects of wheel and track irregularities.

Loads and the corresponding bending moments are the responsibility of the purchaser.

#### 5.4.2 Load distribution

The assembled rail, fastening system and polymeric composite sleepers, bearers and transoms on ballast or other support shall be considered as a beam on a continuous elastic support.

The moment of inertia of the rail profile, the spacing of the polymeric composite sleepers, bearers and transoms, and the elasticity of the whole assembly on its support have an influence on the longitudinal distribution of the vertical wheel loads applied on the rail. As a result, the rail seat load applied on the polymeric composite element is only a proportion of the wheel load.

### 5.5 Characteristic bending moments

The characteristic bending moments shall be determined according to the design criteria for the polymeric composite sleeper, bearer and transom. They are used to calculate test loads.

For the determination of characteristic bending moments, see [Annex B](#) for ballasted track and [Annex C](#) for transoms.

NOTE The method proposed in [Annex B](#) is also used for polymeric composite sleepers, bearers or transoms on elastic layers in ballastless track.

### 5.6 Ecodesign

The supplier and/or manufacturer of polymeric composite sleepers, bearers or transoms shall assess the environmental factors of its products.

The following topics shall be highlighted:

- a) use of hazardous components, including percentage of mass;
- b) use of recycled materials, including percentage of mass;
- c) declaration of energy needed for production (type and quantity), gas emission and other environmental aspects, related to 1 kg of goods;
- d) recycling ways and opportunities, including process description, percentage of mass and energy need;
- e) declaration of transports at each level, from raw materials to customer's border: type of transport, quantity of material.

## 6 Quality control

### 6.1 General

The supplier and/or manufacturer 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 polymeric composite sleepers, bearers and transoms and services that the supplier provides are to the agreed requirements.

The quality manual shall include a quality plan for the production of polymeric composite sleepers, bearers and transoms, which defines and details the following:

- a) the organization, structure and responsibilities;
- b) all the materials, processes and procedures for manufacturing, storing and transporting the polymeric composite sleepers, bearers and transoms;
- c) all testing requirements, including definition of testing equipment, method of testing, frequency of tests, etc.;
- d) all other quality control procedures to ensure and verify that the polymeric composite sleepers, bearers and transoms and services provided are to the agreed requirements of the purchaser.

The purchaser shall have access to the quality manual at the premises of the supplier and/or manufacturer.

NOTE Guidance on quality systems is given in the ISO 9000 family of standards.

Changes to the design, materials or production process from that used to produce the sleepers used in design approval testing shall not be introduced without prior approval from the purchaser. The purchaser may require the repetition of the design approval tests described in this document before approving the changes mentioned above.

### 6.2 Quality control during design approval tests

The supplier shall provide to the purchaser all quality documents in relation to the polymeric composite elements to be submitted to design approval tests.

This includes:

- a) detailed drawings of the polymeric composite element and components included;
- b) material data sheet for the product;

- c) procedure showing how all test requirements are fulfilled:
  - 1) this includes geometrical tests with description of the gauge and measurement method for each dimension;
  - 2) this includes load tests on the polymeric material and the sleeper, bearer or transom with a description of the measurement means and methods;
- d) general description of the manufacturing process;
- e) test report showing conformity of the sleepers with the dimensions and maximum tolerances defined in [Table 2](#).

Design approval tests results may be used for the determination of test loads to be used for routine tests.

### 6.3 Quality control during manufacturing

Before manufacturing, the supplier shall provide to the purchaser a quality plan including all quality documents in relation to the acceptance of materials and manufacturing of the polymeric composite elements.

The quality plan shall explain how the supplier and/or manufacturer will ensure that all sleepers supplied meet the requirements specified by the purchaser.

For routine tests, alternative test arrangements may be used if the supplier and/or manufacturer can provide evidence of results complying with approved test arrangements.

The quality plan shall detail:

- a) frequency of testing for each dimensional requirement;
- b) frequency for load tests on polymeric composite material and on sleeper, bearer or transom;
- c) mechanism used to increase the inspection frequency when defects are identified;
- d) actions to be taken in the case of defects being found to ensure recheck for compliance.

In case of early dimensional inspection of the polymeric composite element, the quality plan shall take into account further shortening of the element.

At the request of the purchaser, the supplier and/or manufacturer can be asked to carry out from time to time certain non-routine tests included in this document and to confirm conformity to this document for the routine tests.

## 7 Documentation

### 7.1 General

The purchaser shall provide all information necessary to design the sleeper, bearer or transom. The supplier shall provide all information necessary for approval of design and manufacture.

### 7.2 Data to be supplied by the purchaser

The purchaser shall specify the following data:

- a) all characteristic bending moments (see [Annex B](#) for ballasted track and [Annex C](#) for transoms);
- b) required tests and choice of options (see [Table 3](#));
- c) acceptance criteria for the selected test, as specified in [8.2](#);

- d) data necessary to perform the selected tests as specified in ISO 12856-2 (depending on the selected tests and options):
- 1) for the permanent deformation test:  $F_{c,perm,n}$ ;
  - 2) for the fatigue test at centre:  $d_{fat,lim}, k_3$ ;
  - 3) for the fatigue test at rail seat:  $d_{fat,lim}, k_3, d_{2s,lim}$ ;
  - 4) for the strength test at rail seat:  $k_{1s}, k_{2s}, d_{1s,lim}, d_{2s,lim}$ ;
  - 5) for the stiffness test with GBP or FP:  $Q_{nom}, L_p$ ;
  - 6) for the compression test with GBP or FP:  $Q_{nom}, L_p, k_{1s}, k_{2s}$ ;
- e) drawings and specifications necessary to define:
- 1) critical dimensions (distance between sleeper gauge points  $L_1$  – length – width – depth at rail seat, etc.);
  - 2) fastening system interface and geometric layout;
  - 3) particular tolerances (see [Table 2](#));
  - 4) conductor rail insulator supports (if applicable);
  - 5) scope of the test arrangements and procedures indicating whether the options are used;
- f) absolute maximum and minimum mass of the polymeric composite sleeper, bearer and transom (kilogram per sleeper or kg/m);
- g) any additional technical specification, e.g. electrical insulation;
- h) rail profile definition;
- i) lower and/or upper limit for material characteristics of polymeric composite (optional).

### 7.3 Data to be provided by the supplier

#### 7.3.1 Before the design approval tests

- a) Detailed drawings of the polymeric composite sleeper, bearer and transom.
- b) Characteristics of materials.
- c) Description of manufacturing process.
- d) Production file for manufacturing data for the sleepers, bearers or transoms produced for the design approval tests.

#### 7.3.2 After the design approval tests

Design approval test report.

#### 7.3.3 Prior to start-up of production

All data required in [Clause 5](#).

## 7.4 Marking

Each polymeric composite sleeper, bearer and transom shall have the following permanent marking:

- a) year of manufacture;
- b) identification mark of the production plant.

The purchaser may require additional information (permanent or not) to be identified on the polymeric composite sleepers, bearers and transoms (i.e. mould identification and/or production machine).

## 8 Product testing

### 8.1 General

This clause defines the product testing for polymeric composite sleepers, bearers and transoms.

Two kinds of tests are used:

- a) design approval test;
- b) routine test: a product test as a part of the manufacturing quality control process.

Tests are defined for each type of polymeric composite sleeper, bearer and transom in ISO 12856-2 and for material in ISO 12856-1.

The routine test procedures are carried out on polymeric composite sleepers, bearers and transoms selected at random from the manufacturing production line. No additional preparation to normal production is allowed. Routine tests are usually assessed on a defined statistical basis.

In some railway networks, dual gauge and convertible gauge sleepers are used. In these cases, the test procedures in this clause may still be used but judgement shall be made by the purchaser on the combination of tests for two gauges.

Any change in design, materials or production process from that used to manufacture the sleepers, bearers or transoms used in the design approval tests shall not be introduced without prior approval of the purchaser. The purchaser may request that the design approval tests described in this document be repeated before approving any changes.

### 8.2 Tests on product

#### 8.2.1 General

[Table 3](#) summarizes the mandatory (M), optional (O) and not applicable (N/A) tests for design approval tests.

The test methods for routine testing shall be agreed between the purchaser and the supplier.

**Table 3 — Matrix of design approval tests in function of track types**

Tests given in ISO 12856-2:2020 <sup>a</sup>	Ballasted track		Ballastless track with elastic layer under the sleeper <sup>b</sup>		Ballastless track without elastic layer under the sleeper <sup>c</sup>		Transom
	Plain track and S&C	Tunnel	Plain track, S&C and bridge	Tunnel	Plain track, S&C and bridge	Tunnel	Bridge with open deck
Stiffness at centre section for negative bending moments in <a href="#">8.2.2.1.1</a>	M	M	M	M	N/A	N/A	M
Fatigue test and ultimate load at centre section for negative bending moments in <a href="#">8.2.2.1.2</a>	M	M	M	M	N/A	N/A	M
Permanent deformation test at centre section for negative bending moments in <a href="#">8.2.2.1.3</a>	O	O	O	O	N/A	N/A	O
Strength test at centre section for negative bending moments in <a href="#">8.2.2.1.4</a>	M	M	M	M	N/A	N/A	M
Stiffness at centre section for positive bending moments in <a href="#">8.2.2.2.1</a>	O	O	O	O	N/A	N/A	N/A
Fatigue test and ultimate load at centre section for positive bending moments in <a href="#">8.2.2.2.2</a>	O	O	O	O	N/A	N/A	N/A
Strength test at centre section for positive bending moments in <a href="#">8.2.2.2.3</a>	O	O	O	O	N/A	N/A	N/A
Stiffness at rail seat in <a href="#">8.2.2.3.1</a>	M	M	M	M	O	O	N/A
Fatigue test at rail seat in <a href="#">8.2.2.3.2</a>	M	M	M	M	O	O	N/A
Strength at rail seat in <a href="#">8.2.2.3.3</a>	M	M	M	M	O	O	N/A
Stiffness with GBP at rail seat in <a href="#">8.2.2.4</a>	O	O	N/A	N/A	N/A	N/A	N/A
Stiffness with FP at rail seat in <a href="#">8.2.2.4</a>	N/A	N/A	O	O	O	O	O
Compression test with GBP at rail seat in <a href="#">8.2.2.5</a>	O	O	N/A	N/A	N/A	N/A	N/A
Compression test with FP at rail seat in <a href="#">8.2.2.5</a>	N/A	N/A	O	O	O	O	O
Thermal expansion in <a href="#">8.2.3</a>	M	O	M	O	M	O	M
<b>Key</b>							
S&C = switches and crossings							
M = mandatory							
O = optional							
N/A = not applicable							
<sup>a</sup> The transoms are tested in ISO 12856-2:2020 with the test procedure for the negative bending moment for sleeper/bearer but with a specific test arrangement.							
<sup>b</sup> Elastic layer corresponds to under sleeper pads or rubber boot.							
<sup>c</sup> Direct transfer of rail seat load to the bridge deck by compression in the polymeric composite element, with negligible bending moment in the sleeper, bearer and transom.							

Table 3 (continued)

Tests given in ISO 12856-2:2020 <sup>a</sup>	Ballasted track		Ballastless track with elastic layer under the sleeper <sup>b</sup>		Ballastless track without elastic layer under the sleeper <sup>c</sup>		Transom
	Plain track and S&C	Tunnel	Plain track, S&C and bridge	Tunnel	Plain track, S&C and bridge	Tunnel	Bridge with open deck
Permanent deformation of screw/insert in function of temperature in <a href="#">8.2.4</a>	M	O	M	O	M	O	M
Fastening system in <a href="#">8.2.5</a>	O	O	O	O	O	O	O
Electrical resistance in <a href="#">8.2.6</a>	O	O	O	O	O	O	O
Screw, spike, cast-in and glued-in fastening component in <a href="#">8.2.7</a>	O	O	O	O	O	O	O
Fire in <a href="#">8.2.8</a>	O	M	O	M	O	M	O
System test in <a href="#">8.2.9</a>	O	O	N/A	N/A	N/A	N/A	N/A
<b>Key</b> S&C = switches and crossings M = mandatory O = optional N/A = not applicable <sup>a</sup> The transoms are tested in ISO 12856-2:2020 with the test procedure for the negative bending moment for sleeper/bearer but with a specific test arrangement. <sup>b</sup> Elastic layer corresponds to under sleeper pads or rubber boot. <sup>c</sup> Direct transfer of rail seat load to the bridge deck by compression in the polymeric composite element, with negligible bending moment in the sleeper, bearer and transom.							

**8.2.2 Bending resistance**

**8.2.2.1 Tests at centre section for negative bending moments**

**8.2.2.1.1 Stiffness in centre section**

This test is used as part of the approval tests to determine the bending stiffness when loaded by a vertical load at the sleeper centre.

The test method is according to ISO 12856-2:2020, 5.2.3.1.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper, bearer or transom tested for fatigue test at the centre section.
- The purchaser shall define the acceptance criteria with  $k_{cn,dyn2}$  between minimum value and maximum value.
- The test report shall include the test results for  $k_{cn,stat1}$ ,  $k_{cn,stat2}$ ,  $k_{cn,dyn1}$  and  $k_{cn,dyn2}$ .
- If this test is used as a routine test the supplier shall provide a reference value of stiffness in the range of purchaser acceptance values.

### 8.2.2.1.2 Fatigue test and ultimate load at centre section for negative bending moments

Settlement of ballast due to repeated loading can lead to sleepers riding on the ballast at the sleeper centre. This test is intended to prove satisfactory fatigue strength for this loading scenario. The effect can occur for ballastless track with plastic deformation of the elastic layer under the sleeper.

The purpose of the fatigue test is to confirm the strength and the variations of the stiffness against the repeated load of the sleeper.

When carrying out the test with the sleepers alone, it is not affected by the other factors (ballast, elastic supports, etc.).

The test method is according to ISO 12856-2:2020, 5.2.3.2.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper, bearer or transom.
- The purchaser shall define the acceptance criteria:
  - $k_{cn,dyn2}$  between minimum value and maximum value;
  - acceptable variation of stiffness ( $\Delta k_{cn,dyn2}$ ) in %;
  - test load at failure  $F_{cB,n} > k_3 \cdot F_{c0n}$ ;
  - visual inspection shall be according to the purchaser's criteria.
- The test report shall include the test results for  $k_{cn,stat1}$ ,  $k_{cn,stat2}$ ,  $k_{cn,dyn1}$ ,  $k_{cn,dyn2}$ ,  $\Delta k_{cn,stat1}$ ,  $\Delta k_{cn,stat2}$ ,  $\Delta k_{cn,dyn1}$ ,  $\Delta k_{cn,dyn2}$  and minimum load to failure or load generating a deflection of 20 mm.

### 8.2.2.1.3 Permanent deformation test at centre section for negative bending moments

Settlement of ballast due to repeated loading can lead to sleepers riding on the ballast at the sleeper centre. This effect can also occur for ballastless track with plastic deformation of the elastic layer under the sleeper. This test is intended to identify permanent deformation.

The test method is according to ISO 12856-2:2020, 5.2.3.3.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper, bearer or transom.
- The purchaser shall define the acceptance criteria:
  - permissible deformation due to  $F_{c,perm,n}$  at the centre of the sleeper measured after removal of the load during the 168 h period;
  - visual inspection shall be according to the purchaser's criteria.
- The report shall include the test load  $F_{c,perm,n}$  and the deformation during the two weeks of the test and the test load applied.

### 8.2.2.1.4 Strength test at centre section for negative bending moments

This test is used to measure the load-deflection curve for negative bending moments from the characteristic load level to the ultimate load level. Minimize the influence of creep deformations during this test.

The test method is according to ISO 12856-2:2020, 5.2.3.4.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper, bearer or transom.
- The purchaser shall define the acceptance criterion: minimum load to failure.
- The test report shall include the load-deflection curve up to failure or maximum deflection 20 mm.

### 8.2.2.2 Tests at centre section for positive bending moments

#### 8.2.2.2.1 Stiffness in centre section

This test is used as part of the approval tests to determine the bending stiffness when loaded by a vertical load at the centre.

The test method is according to ISO 12856-2:2020, 5.2.4.1.

Design approval tests:

- The test method shall be applied on polymeric composite sleepers or bearers tested for fatigue test at the centre section.
- The purchaser shall define the acceptance criterion with  $k_{c,dyn2}$  between minimum value and maximum value.
- The test report shall include the test results for  $k_{c,stat1}$ ,  $k_{c,stat2}$ ,  $k_{c,dyn1}$  and  $k_{c,dyn2}$ .
- If this test is used as a routine test, the supplier shall provide a reference value of stiffness for routine test, in the range of purchaser acceptance values.

#### 8.2.2.2.2 Fatigue test and ultimate load at centre section for positive bending moments

Settlement of ballast due to repeated loading can lead to positive bending moments at the sleeper centre under load. This test is intended to prove satisfying fatigue strength for this loading scenario.

The purpose of the fatigue test is to confirm the strength and the variations of the stiffness against the repeated load of the sleeper.

When carrying out the test with the sleepers alone, it is not affected by the other factors (ballast, elastic supports, etc.).

The test method is according to ISO 12856-2:2020, 5.2.4.2.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper or bearer.
- The purchaser shall define the acceptance criteria:
  - $k_{c,dyn2}$  between minimum value and maximum value;
  - acceptable variation of stiffness ( $\Delta k_{c,dyn2}$ ) in %;
  - test load at failure  $F_{cB} > k_3 \cdot F_{c0}$ ;
  - visual inspection shall be according to the purchaser's criteria.
- The test report shall include the test results for  $k_{c,stat1}$ ,  $k_{c,stat2}$ ,  $k_{c,dyn1}$ ,  $k_{c,dyn2}$ ,  $\Delta k_{c,stat1}$ ,  $\Delta k_{c,stat2}$ ,  $\Delta k_{c,dyn1}$ ,  $\Delta k_{c,dyn2}$  and minimum load to failure or load generating a deflection of 20 mm.

### 8.2.2.2.3 Strength test at centre section for positive bending moments

This test is used to measure the load-deflection curve for positive bending moment from the characteristic load level to the ultimate load level. Minimize the influence of creep deformations during this test.

The test method is according to ISO 12856-2:2020, 5.2.4.3.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper or bearer tested for fatigue.
- The purchaser shall define the acceptance criterion: minimum load to failure.
- The test report shall include the load-deflection curve up to failure or maximum deflection 20 mm.

### 8.2.2.3 Test at rail seat

#### 8.2.2.3.1 Stiffness at rail seat

This test is used as part of the approval tests to determine the bending stiffness when loaded by a vertical load at the rail seat.

The test method is according to ISO 12856-2:2020, 5.2.5.1.

Design approval tests:

- The test method shall be applied on polymeric composite sleepers or bearers tested for fatigue at the rail seat.
- The purchaser shall define the acceptance criteria with  $k_{r,dyn2}$  between minimum value and maximum value.
- The test report shall include the test results for  $k_{r,stat1}$ ,  $k_{r,stat2}$ ,  $k_{r,dyn1}$  and  $k_{r,dyn2}$ .
- If this test is used as a routine test, the supplier shall provide a reference value of stiffness for routine test, in the range of purchaser acceptance values.

#### 8.2.2.3.2 Fatigue test at rail seat

The fatigue test shows the variations of behaviour (stiffness and permanent deformation) of the sleeper at the rail seat under normal service conditions. This test represents short part of service life of the sleeper. It is not intended to test the sleeper until rupture. The variations of behaviour observed show the degradation of the sleepers during the first part of sleeper service life.

The test method is according to ISO 12856-2:2020, 5.2.5.2.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper or bearer.
- The purchaser shall define the acceptance criteria:
  - $k_{r,dyn2}$  between minimum value and maximum value;
  - acceptable variation of stiffness ( $\Delta k_{r,dyn2}$ ) in %;
  - test load at failure  $F_{rB} > k_3 \cdot F_{r0}$ ;
  - visual inspection shall be according to the purchaser's criteria.
- The test report shall include the test results for  $k_{r,stat1}$ ,  $k_{r,stat2}$ ,  $k_{r,dyn1}$ ,  $k_{r,dyn2}$ ,  $\Delta k_{r,stat1}$ ,  $\Delta k_{r,stat2}$ ,  $\Delta k_{r,dyn1}$ ,  $\Delta k_{r,dyn2}$  and minimum load to failure or load generating a deflection  $d_{2s,lim}$ .

### 8.2.2.3.3 Strength at rail seat

This test is used to measure the load-deflection curve for positive bending moment from the characteristic load level to the ultimate load level. Minimize the influence of creep deformations during this test.

The test method is according to ISO 12856-2:2020, 5.2.5.3.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper or bearer.
- The purchaser shall define the acceptance criteria within the list:
  - maximum deformation  $d_{1s}$  for  $k_{1s} \times F_{r0}$ ;
  - maximum deformation or damage for  $k_{2s} \times F_{r0}$ ;
- The test report shall include the load-deflection curve up to failure or maximum deflection  $d_{2s,lim}$ .

### 8.2.2.4 Stiffness with GBP or with FP at rail seat

This test is intended to identify the reduction of the vertical stiffness due to elastic compression of the sleeper body and, in cases of ballasted track, the elastic indentation of the ballast into the sleeper bottom.

The test method is according to ISO 12856-2:2020, 5.3.1.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper, bearer or transom.
- The purchaser shall define the evaluation criteria within the list:
  - $k_{stat}$  between the purchaser minimum value and the purchaser maximum value (average and/or individual value);
  - $k_{max}$  between the purchaser minimum value and the purchaser maximum value (average and/or individual value);
  - $k_{dyn,5Hz}$  between the purchaser minimum value and the purchaser maximum value (average and/or individual value).
- If this test is used as a routine test, the supplier shall provide a reference value of bedding modulus for routine test, in the range of purchaser acceptance values.
- If the test is done according to ISO 12856-2:2020, Annex B or C, the test report shall meet the requirements of ISO 12856-2:2020, B.2.4 and B.3.4.

### 8.2.2.5 Compression with GBP or with FP at rail seat

This test is used to measure the load-deflection curve at the rail seat from the characteristic load level to the ultimate load level.

The test method is according to ISO 12856-2:2020, 5.3.2.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper, bearer or transom.
- The purchaser shall define the acceptance criteria within the list:
  - maximum deformation  $d_{0c}$  for  $F_{r0}$ ;

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- maximum deformation  $d_{1c}$  for  $k_{1s} \times F_{r0}$ ;
- maximum deformation  $d_{2c}$  for  $k_{2s} \times F_{r0}$ .
- The supplier shall provide a reference value of bedding modulus for routine test, in the range of purchaser acceptance values.
- If the test is done according to ISO 12856-2:2020, Annex B or C, the test report shall meet the requirements of ISO 12856-2:2020, B.2.4 and B.3.4.

### 8.2.3 Thermal expansion

The objective of this test is to define the linear thermal expansion coefficient of the sleeper or the bearer.

The test method is according to ISO 12856-2:2020, 5.4.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper, bearer or transom.
- The purchaser shall define the evaluation criteria within the list:
  - $\alpha_{T,top}$  lower or equal to the purchaser maximum value;
  - $\alpha_{T,bottom}$  lower or equal to the purchaser maximum value.
- The report shall include the test results for lengths  $L_0$  and  $L_B$ , temperatures  $T_1$ ,  $T_2$ ,  $T_3$  and  $T_4$ , and coefficients  $\alpha_{T,top}$  and  $\alpha_{T,bottom}$ .

### 8.2.4 Permanent deformation of screw/insert in function of temperature

The objective of this test is to define the permanent deformation of the screw/insert with the polymeric composite sleeper, bearer or transom in function of temperature variations.

The test method is according to ISO 12856-2:2020, 5.5.1.

Design approval tests:

- The test method shall be applied on four screws/inserts.
- The purchaser shall define the evaluation criteria:
  - $\Delta u$  lower or equal to the purchaser maximum value;
  - visual inspection shall be according to the purchaser's criteria.
- The test report shall include the test results for  $u$ , the variation  $\Delta u$  and from visual inspection.

### 8.2.5 Fastening system

These tests are intended to validate the functionality of fastening system in combination with the polymeric composite sleeper, bearer or transom.

The test method is according to ISO 12856-2:2020, 5.5.2.

Design approval tests and acceptance criteria shall be defined by the purchaser.

### 8.2.6 Electrical resistance

This test is intended to validate the electrical insulation of fastening system in combination with the polymeric composite sleeper, bearer or transom.

The test method is according to ISO 12856-2:2020, 5.5.3.

Design approval tests and acceptance criteria shall be defined by the purchaser.

### 8.2.7 Screw, spike, cast-in and glued-in fastening components

These tests are intended to validate the pull-out resistance of fastening system in combination with the polymeric composite sleeper, bearer or transom.

The test method is according to ISO 12856-2:2020, 5.5.4.

Design approval tests and acceptance criteria shall be defined by the purchaser.

### 8.2.8 Fire

Where the sleeper, bearer or transom is proposed for use in tunnel locations, resistance to fire, with particular reference to flammability and smoke emission (toxicity and effects on visibility), shall be demonstrated. For this purpose, the sleeper, bearer or transom shall be tested in the configuration applicable to its proposed application, e.g. set into concrete or ballast up to its top surface.

The test method is according to ISO 12856-2:2020, 5.6.

Design approval tests: The purchaser shall define the test methods and the acceptance criteria for fire tests.

### 8.2.9 System test

This test is intended to validate the behaviour of the sleepers, the bearers or the transoms in the ballast under cyclic loads representing the normal service load.

The test method is according to ISO 12856-2:2020, 5.7.

Design approval tests:

- The test method shall be applied on one polymeric composite sleeper, bearer or transom.
- The purchaser shall define the acceptance criteria:
  - $k_{cn,dyn1}$  between minimum value and maximum value;
  - $\Delta k_{cn,dyn1}$  lower or equal to the maximum percentage;
  - $\Delta m$  lower or equal to the maximum percentage;
  - visual inspection shall be according to the purchaser's criteria.
- The test report shall include the test results for  $k_{cn,stat1}$ ,  $k_{cn,stat2}$ ,  $k_{cn,dyn1}$  and  $k_{cn,dyn2}$ .

## 8.3 Tests on material characteristics

### 8.3.1 Chemical compatibility

The selected tests shall demonstrate that the material of the polymeric composite sleepers is resistant against all those chemicals that can regularly contaminate the sleepers in conventional railway traffic.

The test method is according to ISO 12856-1:2022, 4.1.1.

Design approval tests: The purchaser shall define the acceptance criteria.

### 8.3.2 Environmental resistance

The impact of environmental phenomena on the material properties shall be limited, such that any product property variations are acceptable. The load-bearing capacities of the sleepers until the

end of their service life shall remain sufficient for service regardless of environmental effect. The environmental phenomena to be considered are the following:

- weathering;
- water;
- frost;
- temperature;
- attack by biological media.

Requirements for the material property characteristics are defined in ISO 12856-1:2022, 4.1.2.

The selected tests shall demonstrate that the material of the polymeric composite sleepers is resistant against all those environmental impacts expected in normal operation.

### 8.3.3 Environmental compatibility

The formula of the polymeric composite sleeper is not allowed to contain any chemical, biological or physical environmental contaminants, and/or no negative environmental impact may emanate from it.

The test method is according to ISO 12856-1:2022, 4.2.

Design approval tests: The purchaser shall define the acceptance criteria.

### 8.3.4 Mechanical properties

These tests quantify the mechanical characteristics of the polymeric composite material.

The test method is according to ISO 12856-1:2022, 4.3.

## 8.4 Additional tests for consideration (optional)

### 8.4.1 Damaging of the sleeper surface by ballast

Abrasion can occur at the sleeper surface due to contact with the ballast. Permanent indentation of the ballast into the sleeper bottom can occur as well. The reduction of the load-bearing capacity due to abrasion and indentations shall be taken into account in the design and testing of the sleeper.

The sleeper surface may be textured in order to increase the lateral track resistance.

The purchaser may define the test method in order to measure the impact of cyclic loads on the lateral resistance, mass and surface of sleepers or bearers.

### 8.4.2 Test in track

In order to confirm the compatibility of the polymeric composite sleepers, bearers or transoms, the purchaser may install enough sleepers in track with specific service conditions (tonnage, axle load, speed, radius, environmental conditions, etc.).

A possible reduction of the lateral track resistance during the test in track due to abrasion of the textured surface shall be taken into account.

### 8.4.3 Lateral resistance

The purchaser should define the test method in order to measure the lateral resistance of sleepers, bearers or transoms.

NOTE Lateral resistance of sleeper in track or in laboratory can be tested according to the UIC method<sup>[3]</sup>.

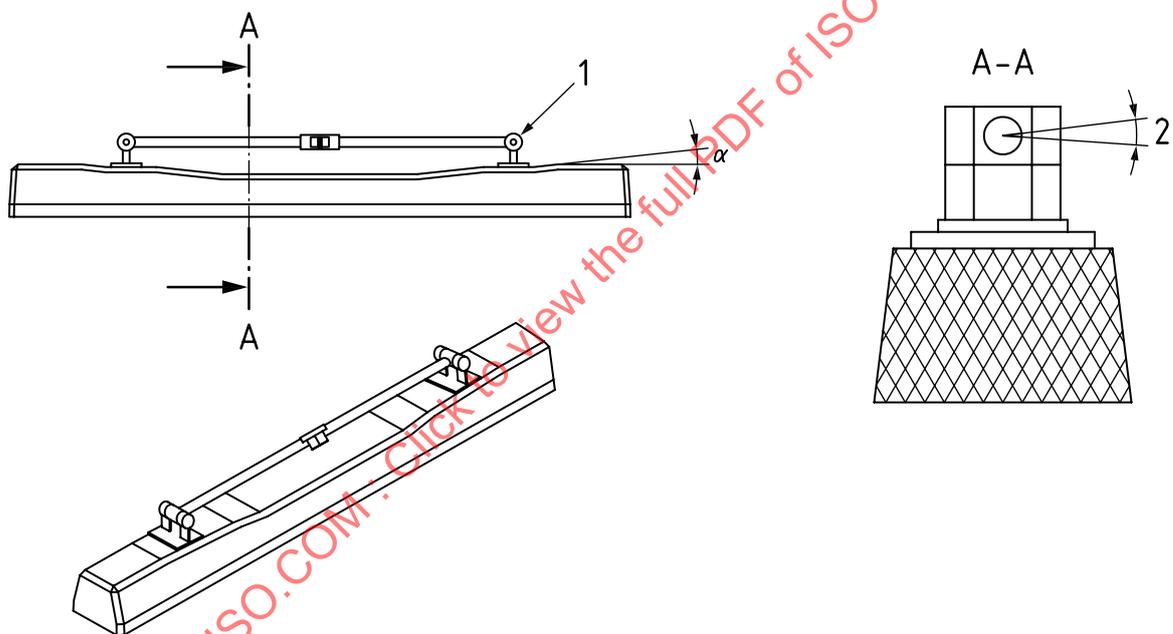
## Annex A (informative)

### Definition and recommendation for measurement of rail seat inclination and twist between rail seats

Rail seat inclination and twist between rail seats shall be evaluated as angle or angle variation between the planes of two rail seats.

For measurement, the reference of each rail seat plane shall be defined by a plate with a minimum length of 150 mm in each direction.

The gauge should be calibrated with a reference sleeper. The reference plate of the rail seat surface should take into account planeness tolerances.



#### Key

- 1 measurement of rail seat inclination
- 2 measurement of twist between rail seats

**Figure A.1** — Example of gauge for measurement of rail seat inclination and twist between rail seats

## Annex B (informative)

### Design methods and factors

#### B.1 Overview

##### B.1.1 General

In ORE D71, a design method using simple beam models combined with factors obtained by track measurements has been established for concrete sleepers. The method assumes a rigid sleeper with constant ballast reaction under the rail seats or over the sleeper length. This method may not be appropriated for polymeric composite sleepers where such assumption is not valid.

NOTE 1 For more details for this method, see EN 13230-6:2020, Annex A.

This method has been developed further in ORE D170 and UIC 713<sup>[4]</sup> for concrete sleepers. As the design method proposed in UIC 713 does not take into account the bending stiffness of the sleeper properly, the design model does not reflect the impact of sleeper deformation on the bending moments in a satisfying way. Especially at the sleeper centre the reduction of local ballast reaction due to deformation of the sleeper leads to a reduction of calculated bending moments.

In order to take into account the elastic properties of sleeper and ballast, the elastic beam on elastic foundation has been established as a suitable design model for the determination of sleeper bending moments.

NOTE 2 As the bending moments calculated with the design method proposed in EN 13230-6 differ from bending moments measured in track, the results of the design model are adapted using calibration factors. This design method is described in detail for concrete sleepers in EN 13230-6:2020, 4.1.3.

Methods and factors presented in this annex follow the same rules. However, the elastic beam on elastic foundation is recommended as design model both for bending moments at the rail seat section and at the sleeper centre section. The rigid beam seems not to be a useful model for polymeric composite sleepers, as polymeric composite sleepers show considerable deformations.

The designation of values such as loads and calibration factors for bending moments reflects the actual state of art. However, there is not yet sufficient experience for giving accurate values for all factors used in the design method. Therefore, the design model described in the following should only be used for pre-design purposes, if no information is available. The capability of polymeric composite sleepers, bearers and transoms to resist repetitive loading and to provide sufficient durability shall be proven by field testing.

Instead of calculating the bending moments with the method described in this annex, the empirical method may be used.

NOTE 3 The description of the empirical method is given in EN 13230-6:2020, 4.1.2.

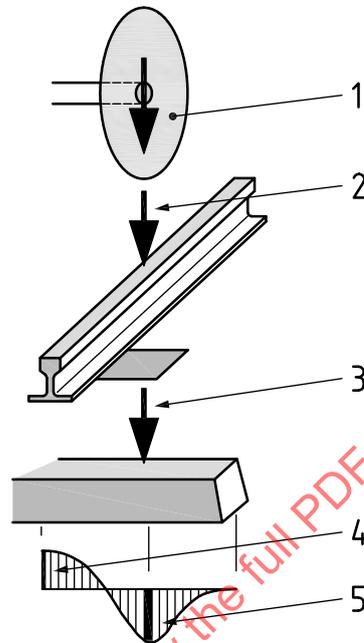
In this case, test criteria for bending moments and acceptable deformations are determined by testing sleepers that have shown satisfying behaviour in track for at least five years in service.

NOTE 4 The method proposed in this annex is also used for polymeric composite transoms on elastic layers in ballastless track. In this case, the coefficients  $k_{i,r}$ ,  $k_{i,c}$  and  $k_t$  are verified by measurements in track.

### B.1.2 Determination of characteristic bending moments

The determination of the characteristic bending moments in the rail seat and sleeper centre follows the vertical flow of forces starting with the nominal axle load within the wheel and ending with the bending moments in the sleeper or bearer.

In [Figure B.1](#), all relevant factors have been presented including the corresponding formulae.



#### Key

- 1  $\frac{A_{\text{nom}}}{2}$
- 2  $Q_k = \frac{A_{\text{nom}}}{2} \cdot (1 + k_v)$
- 3  $P_k = \frac{A_{\text{nom}}}{2} \cdot (1 + k_v \cdot k_p) \cdot k_d \cdot k_r$
- 4  $M_{k,c,neg}$
- 5  $M_{k,r,pos} = k_{ir} \cdot P_k \cdot \frac{l}{2}$

**Figure B.1 — Load distribution for the determination of bending moments**

[Figure B.1](#) points out the effect of the wheel load on the different track components.

For the determination of the longitudinal load distribution within the rail, the model of the beam on elastic foundation may be applied.

The same method may be used for the determination of the bending moments in sleepers and bearers.

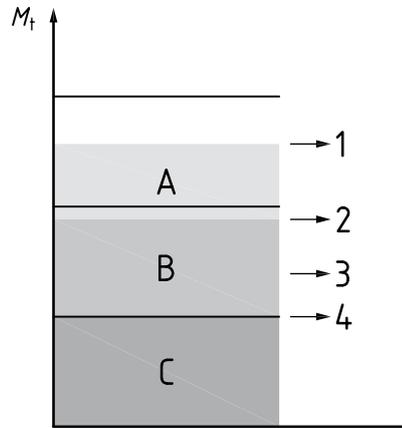
The determination of bending moments as shown is limited to static and dynamic service loads. Exceptional and accidental loads are not taken into consideration.

It should be noted that the vertical load flow shown in [Figure B.1](#) only depicts the chosen model with its different load phases. The dynamic interaction of wheel, rail and sleeper or bearer was omitted in order to simplify the figure.

### B.1.3 The determination of test bending moments

All test bending moments are directly related to the characteristic bending moments.

The load levels presented in [Figure B.2](#) indicate different levels of testing.



**Key**

- A accidental loads
- B exceptional loads
- C service loads

The load levels presented in [Figure B.2](#) indicate different levels of testing.

- 1 The accidental load level [ $k_2 \times M_k$  or  $k_3 \times M_k$ ] is limited by the ultimate load test.
- 2 At the exceptional load level [ $k_1 \times M_k$ ], no damage may appear at the sleeper or bearer.
- 3 In the increased service load level test [ $k_t \times M_k$ ], the time dependent factor  $k_t$  covers the decrease of bending resistance and stiffness with time. This load level is used for materials that show degradation of their mechanical properties during service life.
- 4 The service load level [ $M_k$ ] corresponds to the characteristic bending moment. It is used for materials that do not show degradation of their mechanical properties during service life.

**Figure B.2 — Load levels and bending moments for testing**

In the service load level or the increased service load level no damage or plastic deformation shall appear due to test bending moments. The acceptance criteria for deformations or change of gauge shall not be exceeded. The test with time dependent factor,  $k_t$ , secures the required bending resistance and stiffness over the entire service life.

In the exceptional load level, no damage may appear. Elastic and permanent plastic deformations may not exceed the limits given by the requirements of rolling stock.

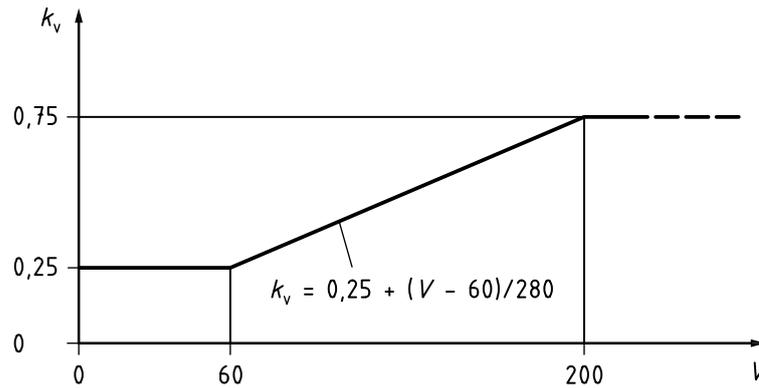
In the accidental load level, the sleeper may be severely damaged. However, the basic functions of a sleeper such as guiding the vehicles and transferring loads to the ballast shall still be available.

## B.2 Rail seat load

### B.2.1 Normal service increment for the dynamic wheel load

The dynamic wheel load,  $Q_k$ , is calculated with [Formula \(B.1\)](#) from the nominal axle load,  $A_{nom}$ , using the factor,  $k_v$ , for the influence of speed and track condition:

$$Q_k = Q_{nom} \cdot (1 + k_v) = \frac{A_{nom}}{2} \cdot (1 + k_v) \tag{B.1}$$

**Key**

$V$  train speed in km/h  
 $k_v$  factor in function of the train speed  $V$

for  $0 \leq V \leq 60$  km/h:  $k_v = 0,25$

for  $60 < V < 200$  km/h:  
 $k_v = 0,25 + \frac{V - 60}{280}$

for  $V \geq 200$  km/h:  $k_v = 0,75$

Recommendation 1: For a track with usual vertical alignment defects and depressions, the normal service dynamic increment factor  $k_v$  should be taken from [Figure B.3](#).

**Figure B.3 — Factor  $k_v$**

The factor  $k_v$  has been derived from measurement in track with usual levelling defects and depressions. It corresponds to the mean value plus two times the standard deviation of the dynamic wheel load. For a track with a high maintenance level (e.g. high-speed lines), lower values of  $k_v$  can be appropriated.

## B.2.2 Distribution of vertical loads in longitudinal direction

### B.2.2.1 Theoretical distribution

The longitudinal distribution of the wheel loads by the rails between sleepers along the track may be calculated using the model of the elastic beam on elastic foundation. The influence of all elastic track components may be taken into account. In addition, the elastic compression of the polymeric composite sleeper body under the rail seat and the elastic indentation of the ballast into the sleeper bottom may be taken into account. Attention should be paid regarding the stiffness,  $c_{tot}$ , for one support of the rail. [Formulae \(B.2\) to \(B.9\)](#) are for the calculation of the load distribution factor,  $k_d$ .

— Stiffness of ballast and subsoil for one support (half a sleeper),  $c_B$ , in N/mm:

$$c_B = 0,5 \cdot A_R \cdot C_B \quad (\text{B.2})$$

where

$A_R$  is the bearing area of the sleeper, in  $\text{mm}^2$ ;

$C_B$  is the bending modulus for ballast and subgrade, in  $\text{N/mm}^3$ .

— Stiffness for one support of the rail,  $c_{tot}$ , in N/mm:

$$c_{tot} = \left( \frac{1}{c_P} + \frac{1}{c_S} + \frac{1}{c_B} \right)^{-1} \quad (\text{B.3})$$

where

$c_p$  is the stiffness of the rail pad for dynamic loads, in N/mm;

$c_s$  is the stiffness of the sleeper body including ballast indentation (if present), in N/mm;

$c_B$  is the stiffness of ballast and subsoil, in N/mm.

— Elastic length,  $L_{el}$ , in mm, of the Winkler beam:

$$L_{el} = \sqrt[4]{\frac{4 \cdot E_R \cdot I_R}{c_{tot} / a}} \quad (B.4)$$

where

$E_R$  is the modulus of elasticity of the rail, in N/mm<sup>2</sup>;

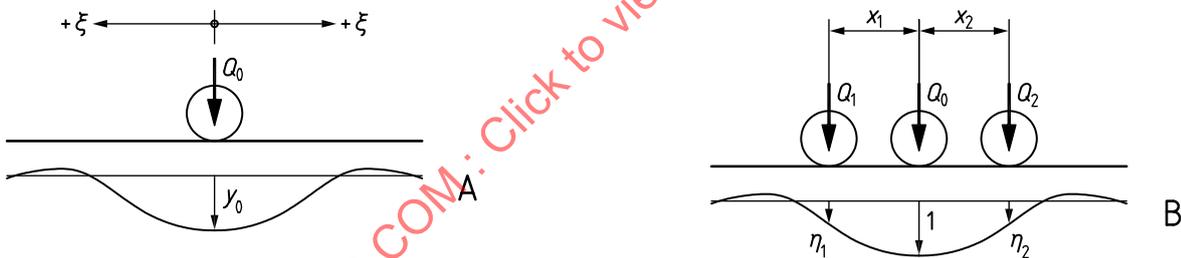
$I_R$  is the moment of inertia of the rail, in mm<sup>4</sup>;

$a$  is the sleeper spacing, in mm.

— Rail deflection,  $y_0$ , in mm, for a unit wheel load,  $Q_0$ :

$$y_0 = \frac{Q_0 \cdot a}{2 \cdot c_{tot} \cdot L_{el}} \quad (B.5)$$

— Influence,  $\eta$ , of the axle positions,  $x_i$  (see [Figure B.4](#)):



**Key**

- A deflection of the rail
- B line of influence of multiple axles

**Figure B.4 — Axle positions,  $x_i$**

$$\eta_i = \frac{\sin \xi_i + \cos \xi_i}{e^{\xi_i}} \quad (B.6)$$

where

$$\xi_i = \frac{x_i}{L_{el}} \quad (\text{rad}) \quad (B.7)$$

— Rail seat load,  $P_0$ , in N, due to a unit wheel load,  $Q_0$ :

$$P_0 = c_{tot} \cdot y_0 \cdot \sum \eta_i \quad (B.8)$$

— Load distribution factor:

$$k_d = \frac{P_0}{Q_0} \quad (\text{B.9})$$

Measurement in track showed that  $k_d$  corresponds to the mean value of longitudinal load distribution.

Recommendation 1: The value of  $k_d = 0,5$  used for track with concrete sleepers with rails  $\geq 46$  kg/m and a sleeper spacing  $\leq 65$  cm should only be used for polymeric composite sleepers which are at least as stiff as hard wood sleepers.

Recommendation 2: If the factor  $k_d$  is calculated using the beam on elastic foundation, it is recommended to use  $C_B = 0,1$  N/mm<sup>3</sup> for typical formation conditions in combination with  $k_{i,r}$ ,  $k_{i,c,neg}$  and  $k_{i,c,pos}$  (see below).

Recommendation 3: The stiffness  $c_B$  calculated with [Formula \(B.2\)](#) is a conservative estimate, as a rigid sleeper is assumed. A more accurate value can be found using the model of the elastic beam on elastic foundation (see below) for the sleeper and calculating  $c_B$  from the deflection of the sleeper at the rail seat centre.

### B.2.2.2 Effect of support faults

The variation of the sleeper reaction between sleepers due to ballast support faults is taken into account by the factor  $k_r$ . Measurement in track with wooden sleepers or concrete sleepers showed that the coefficient of variation leads to an increase of the rail seat load up to 35 %.

It is recommended to use  $k_r = 1,35$ .

### B.2.3 Attenuation effects of elastic rail pads and of elastic sleeper body

Attenuation effects of an elastic rail pad and an elastic sleeper body may be taken into account using the load decrease factor  $k_p$ .

If the polymeric composite sleeper, bearer or transom can be considered as an elastic sleeper body which absorbs impact, Recommendation 1 may be used. If not, Recommendation 2 may be used.

Recommendation 1: The following values of  $k_p$  should be used:

- for pads with low attenuation (< 15 %):  $k_p = 0,70$
- for pads with medium attenuation (15 % to 30 %):  $k_p = 0,68$
- for pads with high attenuation (> 30 %):  $k_p = 0,66$

Recommendation 2: The following values of  $k_p$  should be used:

- for pads with low attenuation (< 15 %):  $k_p = 1,0$
- for pads with medium attenuation (15 % to 30 %):  $k_p = 0,89$
- for pads with high attenuation (> 30 %):  $k_p = 0,78$

NOTE The factor  $k_p$  can be determined according to EN 13146-3 as the mean value of several tests.

### B.2.4 Calculation of the dynamic rail seat load

The characteristic rail seat load,  $P_k$ , is calculated taking into account the effects of speed, the load distribution of the rails, the vibration attenuation of the rail pads and the sleeper body, and the effect of support faults along the sleeper length.

The characteristic value of the rail seat load,  $P_k$ , may be calculated with [Formula \(B.10\)](#):

$$P_k = \frac{A_{\text{nom}}}{2} \cdot (1 + k_p \cdot k_v) \cdot k_d \cdot k_r \quad (\text{B.10})$$

### B.3 Characteristic bending moments

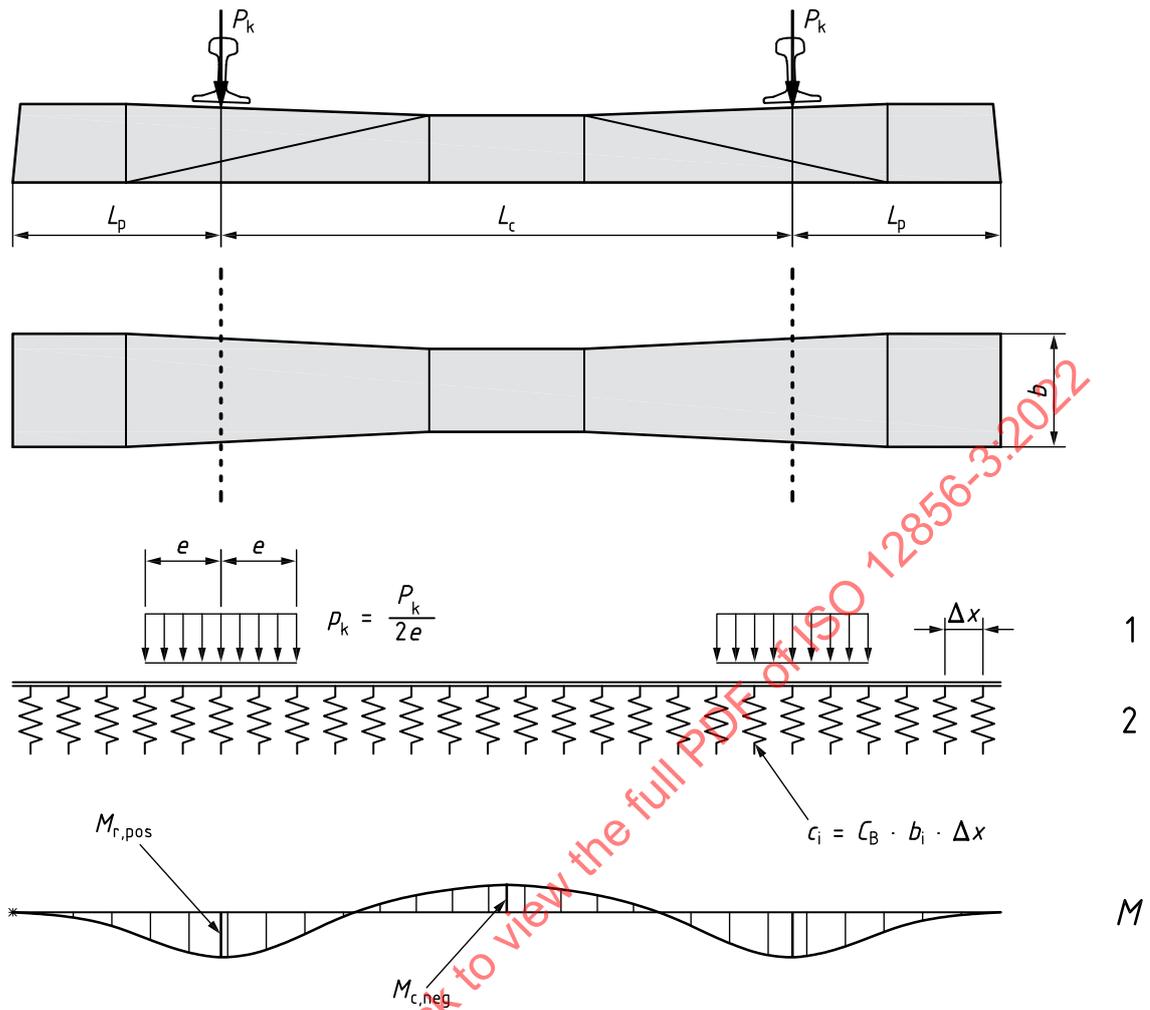
#### B.3.1 General

For the calculation of the characteristic bending moments, the uneven distribution of the ballast reaction under the sleeper and the elasticity of the sleeper should be taken into account. The elastic beam on elastic foundation may be used as design model for the sleeper.

#### B.3.2 Calculation using the elastic beam on elastic foundation

The calculation may be performed using the finite element method for an elastic beam on elastic foundation. Beam elements or volume elements may be used. The example shown in [Figure B.5](#) uses beam elements.

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**Key**

- $b$  bottom width
- 1 elastic beam
- 2 spring elements
- $M$  bending moment, in kNm

**Figure B.5 — Finite element model for the elastic beam on elastic foundation**

**B.3.3 Load distribution for the rail seat load**

The rail seat load,  $P_k$ , should be replaced by a line load,  $p_k$ , over the length  $2e$  according to [Figure B.6](#).

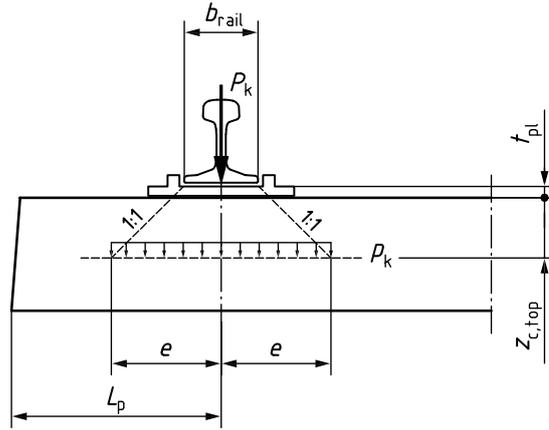


Figure B.6 — Simplified model for the load distribution for the rail seat load

The distance from the sleeper end to the centre line of the rail seat is calculated with [Formula \(B.11\)](#):

$$L_p = \frac{L - L_c}{2} \quad (B.11)$$

where

$L$  is the length of the sleeper;

$L_c$  is the design distance between the centre lines of the rail seats.

The load distribution in the sleeper body under the rail foot is calculated with [Formula \(B.12\)](#):

$$2e = b_r + 2 \cdot (z_{c,top} + t_{pl}) \quad (B.12)$$

where

$b_r$  is the width of the rail foot;

$t_{pl}$  is the thickness of the plate, if present (e.g. base plate);

$z_{c,top}$  is the distance from top surface of the sleeper to the neutral axis;

$2e$  is the assumed length of a constant distributed load,  $p_k$ .

### B.3.4 Rail seat section

#### B.3.4.1 Positive bending moment

A positive bending moment,  $M_{r,pos}$ , is calculated from  $P_k$  using the beam on elastic foundation with a constant bedding modulus over the length  $2L_p$ , assuming that there is no ballast reaction over the length  $L - 4L_p$  at the sleeper centre (see [Figure B.7](#)).