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Plastics — Plastic railway sleepers for railway applications (railroad ties) —

Part 1: Material characteristics

Plastiques — Traverses en plastique pour les applications ferroviaires (traverses de voie ferrée) —

Partie 1: Propriétés des matériaux

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Foreword

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 61, *Plastics*, Subcommittee SC 11, *Products*.

ISO 12856 consists of the following parts, under the general title *Plastics — Plastic railway sleepers for railway applications (railroad ties)*:

— *Part 1: Material characteristics*

The following parts are planned:

— *Part 2: Products*

Introduction

Railway sleepers are manufactured mainly of pre-stressed concrete, wood, or steel. However, based on the development of plastic materials, some plastic sleepers have been installed in recent years.

In view of the facts that the types of plastics and manufacturing processes can have various effects on the in-service performance, this part of ISO 12856 covers the general characteristics of materials which plastic/composite sleepers are made from, in order to specify their performance.

This part of ISO 12856 will be used in conjunction with ISO 12856-2 to be developed in the foreseeable future.

This part of ISO 12856 applies to sleepers made from plastic materials, including reinforced plastic materials.

Plastics — Plastic railway sleepers for railway applications (railroad ties) —

Part 1: Material characteristics

1 Scope

This part of ISO 12856 specifies the characteristics of plastic and reinforced plastic materials to be used in the manufacturing of railway sleepers.

It is applicable to the sleepers and parts of sleepers to be installed in tracks with or without ballast. Examples of different types of plastic and reinforced sleepers are given in Annex B.

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.

ISO 62, *Plastics — Determination of water absorption*

ISO 75 (all parts), *Plastics — Determination of temperature of deflection under load*

ISO 178, *Plastics — Determination of flexural properties*

ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 306, *Plastics — Thermoplastic materials — Determination of Vicat softening temperature (VST)*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

ISO 527-4, *Plastics — Determination of tensile properties — Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*

ISO 604, *Plastics — Determination of compressive properties*

ISO 877-1:2009, *Plastics — Methods of exposure to solar radiation — Part 1: General guidance*

ISO 877-2:2009, *Plastics — Methods of exposure to solar radiation — Part 2: Direct weathering and exposure behind window glass*

ISO 1183-1, *Plastics — Methods for determining the density of non-cellular plastics — Part 1: Immersion method, liquid pyknometer method and titration method*

ISO 2578, *Plastics — Determination of time-temperature limits after prolonged exposure to heat*

ISO 3611, *Geometrical product specifications (GPS) — Dimensional measuring equipment: Micrometers for external measurements — Design and metrological characteristics*

ISO 4892-2, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 4892-4, *Plastics — Methods of exposure to laboratory light sources — Part 4: Open-flame carbon-arc lamps*

ISO 8256, *Plastics — Determination of tensile-impact strength*

ISO 10640, *Plastics — Methodology for assessing polymer photoageing by FTIR and UV/visible spectroscopy*

ISO 11357-2, *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature and glass transition step height*

ISO 11357-6, *Plastics — Differential scanning calorimetry (DSC) — Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)*

ISO 11359-2, *Plastics — Thermomechanical analysis (TMA) — Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature*

ISO 13385-1, *Geometrical product specifications (GPS) — Dimensional measuring equipment — Part 1: Callipers; Design and metrological characteristics*

ISO 13385-2, *Geometrical product specifications (GPS) — Dimensional measuring equipment — Part 2: Calliper depth gauges; Design and metrological characteristics*

ISO 14125, *Fibre-reinforced plastic composites — Determination of flexural properties*

ISO/TR 19032, *Plastics — Use of polyethylene reference specimens (PERS) for monitoring laboratory and outdoor weathering conditions*

IEC 60695-11-20:2003, *Fire hazard testing — Part 11-20: Test flames — 500 W flame test methods*

3 Characteristics

3.1 Material identification

The manufacturer shall declare the following information:

a) type of polymer(s), e.g. thermoplastic or thermosetting, including the main additives and the materials constituting composite matrix, if any;

b) type, form, structure, and content of reinforcing materials;

c) type, form, and content of filler or increasing-mass materials, if any;

d) description of the manufacturing process.

3.2 Chemical resistance

The material shall not be adversely affected by exposure to chemicals typically found in the railway environment, such as diesel and grease. Chemical compatibility can be demonstrated either by test results or it can be documented.

3.3 Physical, mechanical, and electrical characteristics

The physical, mechanical, and electrical characteristics of materials are listed in Tables 1 and 2. The relevance of assessment on characteristics shall be agreed on between the interested parties. Some of the tests might not be applicable for anisotropic sleepers or sleepers with specific reinforced material.

Examples of typical plastic sleeper properties are given in Annex B.

Table 1 — Physical, mechanical, and electrical characteristics

Characteristic		Unit	Test method
Material strength	Bending strength	MPa	4.2
	Flexural modulus	MPa	
	Longitudinal compression strength	N/mm^2	4.3
	Lateral compression strength	N/mm^2	4.4
	Shear strength	N/mm^2	4.5
	Adhesive shear strength	N/mm^2	4.6
Electrical characteristic	Alternating-current breakdown voltage	kV	4.7
	Direct-current insulation resistance	Ω	4.8
Water absorption		%[a]	4.9
Mass density		g/cm^3	4.10
Linear expansion coefficient		K^{-1}	4.11

[a] Percentage expressed in mass fraction.

Table 2 — Temperature-dependent mechanical properties

Characteristic		Unit	Test conditions	Test method
Material strength	Bending strength	%[a]	In air for 24 h Test temperatures[b]: −30 °C and 60 °C	4.2
	Flexural modulus	%[a]		
	Longitudinal compression strength	%[a]		4.3
	Shear strength	%[a]		4.5

[a] Percentages indicate the strength retention in comparison with the values determined at an ambient temperature.

[b] Test temperatures can vary in the conditions where sleepers are used (tunnels, extreme weather conditions, excessively exposed locations).

3.4 Weathering resistance

The sleeper shall be designed to guarantee that at the end of its service life, the load-bearing capacities are sufficient for service even in case of the losses of strength due to weathering.

The requirements for the weathering resistance of the materials shall be agreed on between the interested parties.

The weathering resistance shall be demonstrated either by a documented and substantially proven experience or by assessing the properties in accordance with 4.13.1 or 4.13.2, as applicable.

4 Test methods

4.1 General

4.1.1 Preparation of test specimens

There shall be no damage or faults on the surface of the test specimens in order to prevent notch effects. If there are burrs, they shall be carefully removed without damaging the surface. If necessary, the edges of the surfaces of the test specimens shall be finished using sandpaper.

4.1.2 Test conditions

Unless otherwise specified in a separate clause, the test shall be carried out in one of the standard atmospheres specified in ISO 291 after the test specimens are conditioned in the same atmosphere for at least 24 h.

4.1.3 Tolerance of test specimens

For each test method, the dimensions of the test specimens should be given with tolerances. The nominal dimension shall be ±1 mm.

4.2 Bending strength and flexural modulus

The test shall be conducted at (23 ± 5) °C using the following method.

The longitudinal direction of the test specimen shall be parallel to the supports and vertical to the load direction. A steel plate of dimensions 3 mm × 50 mm × 50 mm shall be placed on the test specimen and positioned in the middle between the supports.

The dimensions of the test specimen shall be:

— length: (240 ± 2) mm,

— width: (50 ± 1) mm,

— thickness: (20 ± 1) mm,

and the span between supports shall be 160 mm to 200 mm.

The concentrated load shall be applied in the middle of the span. The average loading speed (stress) shall be less than 15 N/mm^2 per minute.

The support shall be robust enough and have sufficient area to touch the test specimen. Both supports shall be located on the same distances from the centre of the test specimen in the longitudinal direction.

The other details of test arrangements shall refer to ISO 178.

4.3 Longitudinal compressive strength

The longitudinal compressive strength test shall be conducted at (23 ± 5) °C and using the following method.

The dimensions of the test specimen shall be:

— length: (40 ± 2) mm,

— width: (20 ± 0,5) mm,

— thickness: (20 ± 0,5) mm.

The longitudinal direction of the test specimen is corresponding to the longitudinal direction of the sleeper. The loading direction shall be parallel to the longitudinal direction of the test specimen.

The loading pressure shall be applied to the test specimen where the specimen is located between two flat steel plates. The average loading speed (stress) shall be less than 15 N/mm^2 per minute.

The other details of test arrangements shall be referred to ISO 604.

4.4 Lateral compressive strength

The lateral compressive strength test shall be conducted at (23 ± 5) °C using the following method.

The test specimen shall be cut with a length between 500 mm and 700 mm and a width 200 mm and thickness 100 mm. The loading direction shall be vertical to the longitudinal direction of test specimen.

The loading pressure shall be applied to the test specimen using the flat steel plates both on its top and bottom sides. The average loading speed (stress) shall be less than 15 N/mm^2 per minute.

The other details of test arrangements shall be referred to ISO 604.

4.5 Shear strength

The shear strength test shall be conducted at (23 ± 5) °C using the following method.

The loading pressure shall be parallel to the longitudinal direction of test specimen. The loading pressure shall be applied by the method illustrated in Figure 1. The average loading speed (stress) shall be less than 5,88 N/mm^2 per minute.

The rectangular test specimen with dimensions 40 mm × 50 mm × 52 mm shall be prepared with a cut portion of 10 mm × 10 mm × 40 mm as shown in Figure 2.

The maximum load refers to the load before the test specimen begins to break (not to deform).

The setting jig shall be robust enough and have sufficient areas to touch the test specimen. In addition, as illustrated in Figure 1, the setting jig shall have the necessary capacity to hold the test specimen so as not to be moved even though load is given on the edge of the test specimen.

The tolerance of radius of curvature of the edge of the cut portion and the roughness of contact surface between the loading block and the test specimen can be defined on the agreement between the interested parties.

The shear strength shall be determined from the test results using Formula (1).

$$\tau = \frac{P_{\mathrm{m}}}{A} \tag{1}$$

where

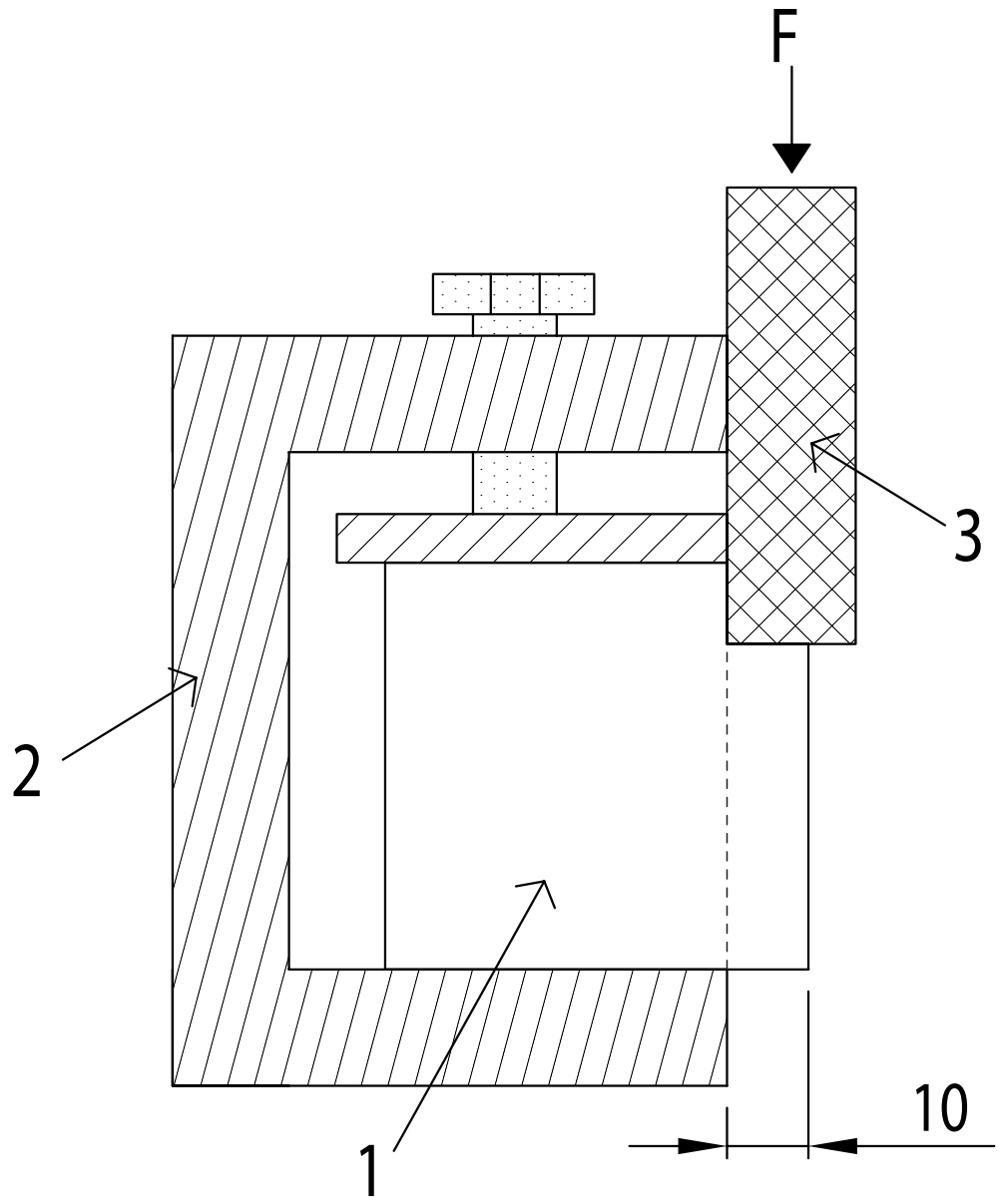
τ is the shear strength (N/mm^2);

P_{m} is the maximum load (N);

A is the cross-sectional area (mm^2).

NOTE Refer to ISO 604 for the definition of “maximum load”.

Dimensions in millimetres

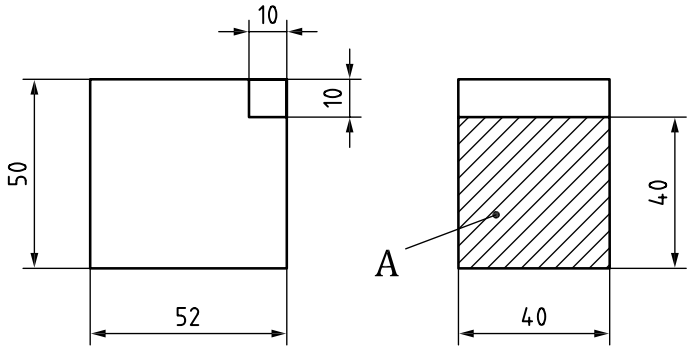


Key

1 specimen
2 setting jig
3 loading block
F load (or force)

Figure 1 — Loading method for shear strength test

Dimensions in millimetres



Key

A cross-sectional area

Figure 2 — Test specimen for shear strength test

4.6 Adhesive shear strength

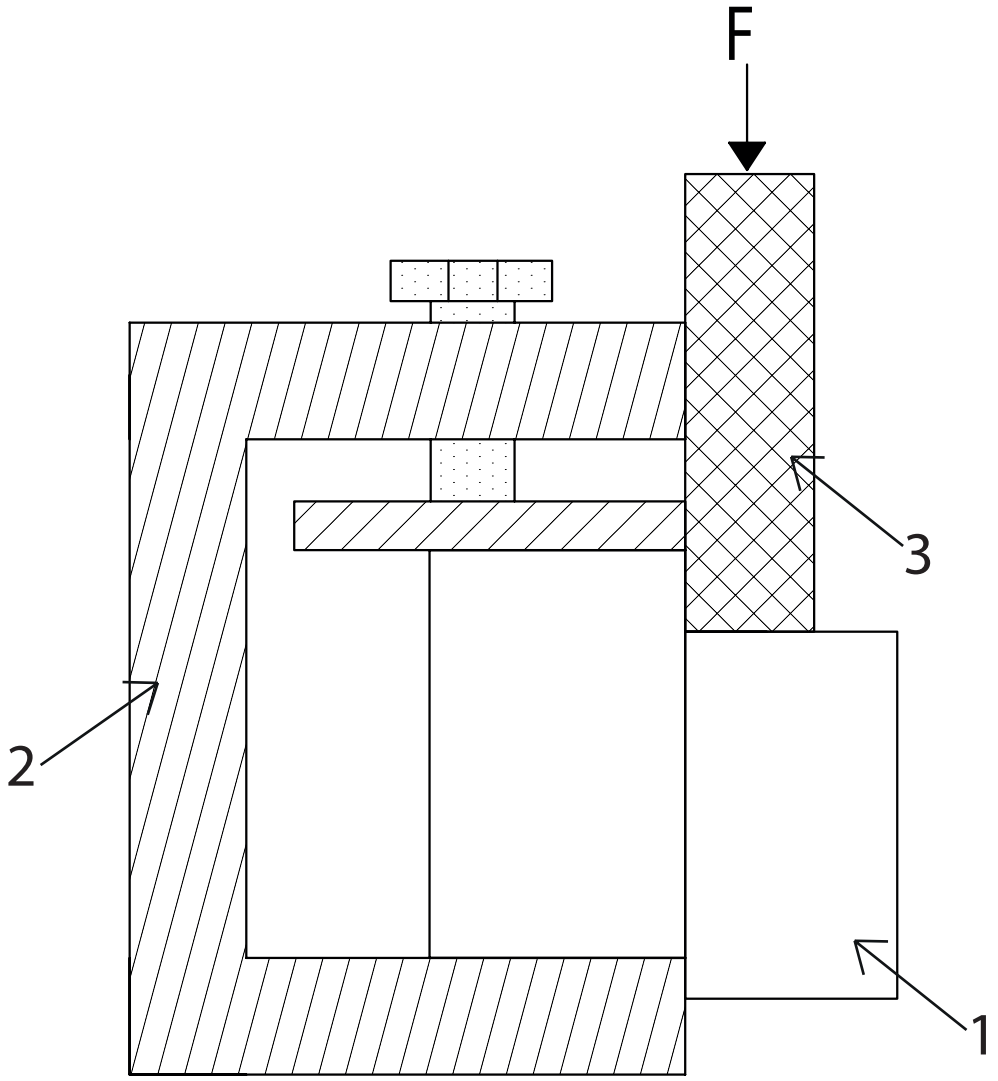
For testing, the adhesive material or the method of use shall not be specified.

The adhesive shear strength test shall be conducted at (23 ± 5) °C using the following method. Alternatively, the test specimen shall be cut out from pre-prepared glued material and then finished to the shape and dimension as illustrated in Figure 7. The loading direction shall be parallel to the longitudinal direction of the test specimen and the surface coated with adhesive. The average loading speed (stress) shall be adjusted to less than 9,8 kN/min. The travel speed of the crosshead shall be adjusted to be between 0,3 mm/min and 0,5 mm/min, and the loading pressure shall be as given in the method shown in Figure 6.

The perimeter of the glued surface shall be free from an excess of adhesive. This clause shall apply only to laminated materials.

The maximum load shall be the load before the test specimen begins to break (not to deform).

The setting jig shall be robust enough and have sufficient areas to touch the test specimen. In addition, as illustrated in Figure 3, the setting jig shall have the necessary capacity to hold the test specimen so as not to be moved even though load is given on the edge of test specimen.

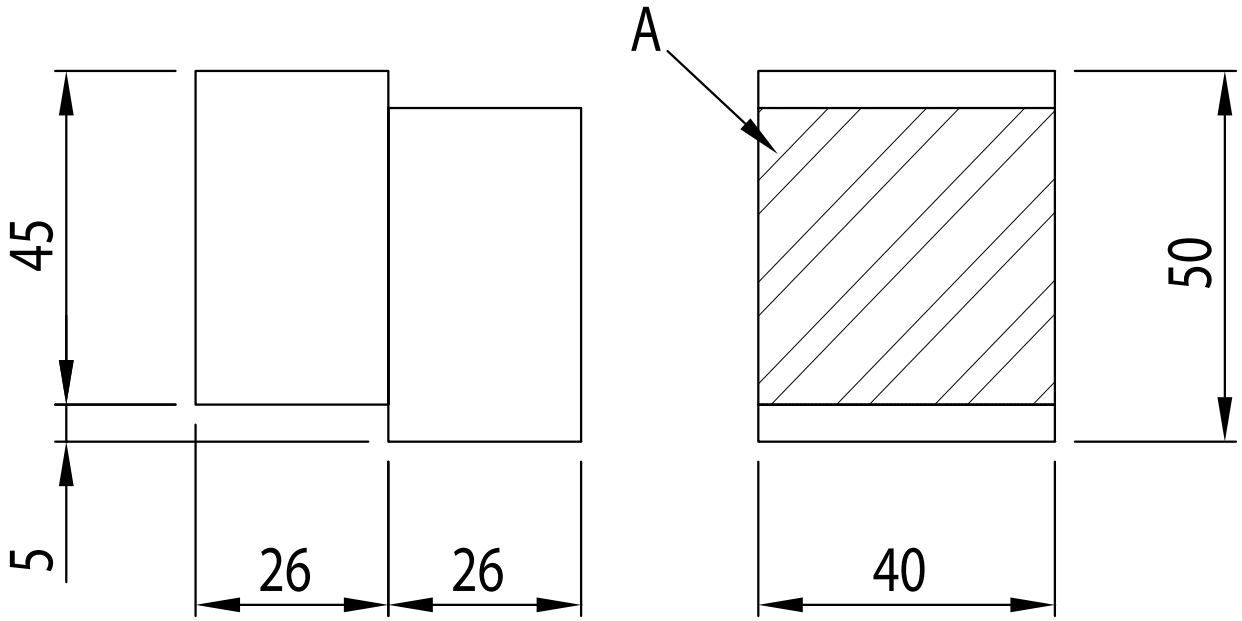


Key

1 specimen
2 setting jig
3 loading block
F load

Figure 3 — Loading method for shear strength test

Dimensions in millimetres



Key

A adhesion surface area

Figure 4 — Test specimen for shear strength test

The adhesive shear strength shall be determined from the test results using Formula (2).

$$S = \frac{P_m}{A} \tag{2}$$

where

S is the shear strength (N/mm^2);

P_m is the maximum load (N);

A is the adhesive surface area (mm^2).

NOTE Refer to ISO 604 for the definition of "maximum load".

4.7 Alternating-current breakdown voltage

The alternating-current breakdown voltage test shall be conducted using the following method.

The test specimen with the dimensions 20 mm × 80 mm × 100 mm, as shown in Figure 5, shall be prepared. The longitudinal axis in testing shall be parallel to the longitudinal direction of test specimen.

Prior to the test, the specimen shall be conditioned at (23 ± 1) °C for 48 h. The shape of the electrode shall be as shown in Figure 6. The electrode equipment shall be set at the central points on the top and bottom surfaces of the test specimen.

The contact pressure between the electrode equipment shall be about 5 kN. The voltage application method shall be as in that of a short-time breakdown test. The value of alternating-current breakdown voltage shall be measured by applying the voltage beginning from 0 V at the speed where insulation breakdown occurs in between 10 s and 20 s (alternating-current breakdown voltage shall be measured here).

It is recommended that the test be conducted at (23 ± 1) °C air temperature with an application of silicon oil to prevent an air short-circuit.

Applicability of this test can be determined by the interested parties.

Dimensions in millimetres

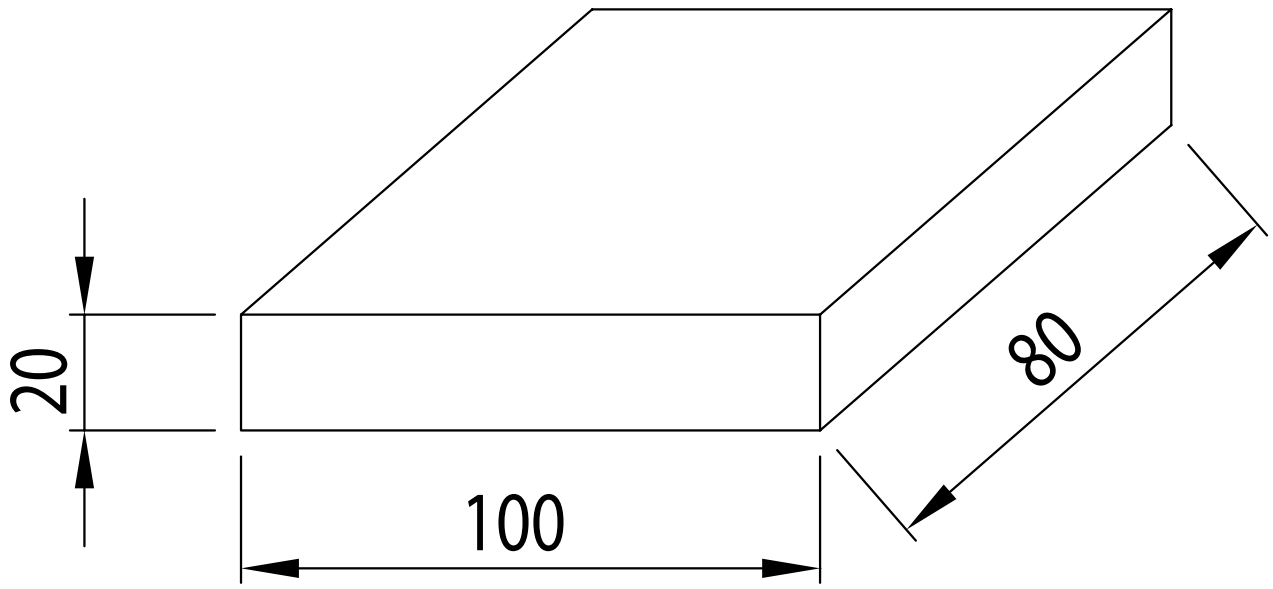
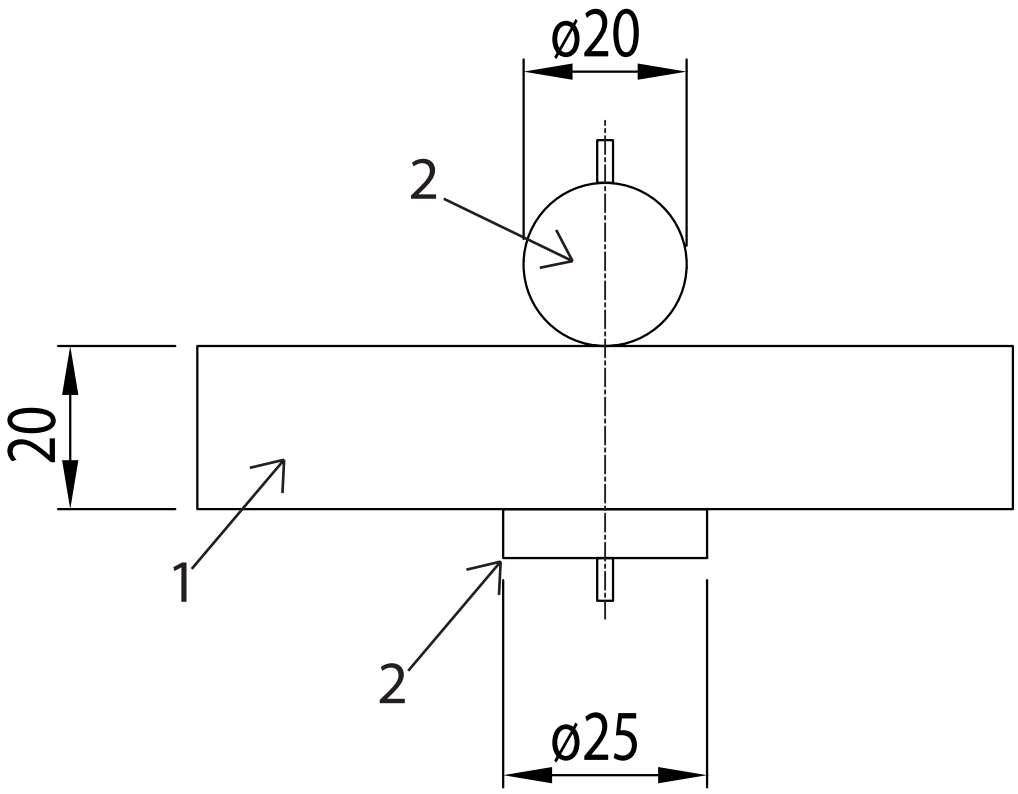


Figure 5 — Test specimen for alternating-current breakdown voltage test

Dimensions in millimetres



Key

1 specimen

2 electrode

Figure 6 — Electrode shape for alternating-current breakdown voltage test

4.8 Direct-current insulation resistance

The direct-current insulation resistance test shall be conducted at (23 ± 5) °C using the following method.

The test specimen with the dimensions 5 mm × 20 mm × 40 mm shall be prepared. The longitudinal axis in testing shall be parallel to the longitudinal direction of the test specimen.

Prior to the test, the specimen shall be conditioned at (23 ± 1) °C in air for 48 h. Then, two holes shall be made and finished by a taper pin reamer for insertion of the electrode as illustrated in Figure 7.

The test shall be conducted with the devices composed of electrode, power supply, galvanometer, universal shunt, switch, etc. in order to measure the direct-current insulation resistance as shown in Figure 8.

For the electrode, the brass taper pin with 5 mm diameter, which should be free from flaws on the surface, shall be used. The power supply shall be equipped with a dry cell or a storage battery of 500 V in the direct voltage.

Applicability of this test can be determined by the interested parties.

Dimensions in millimetres

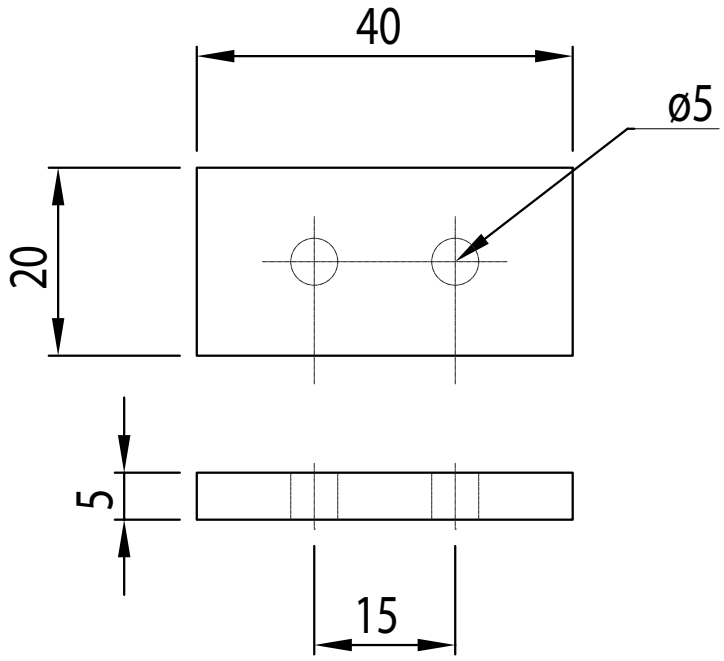
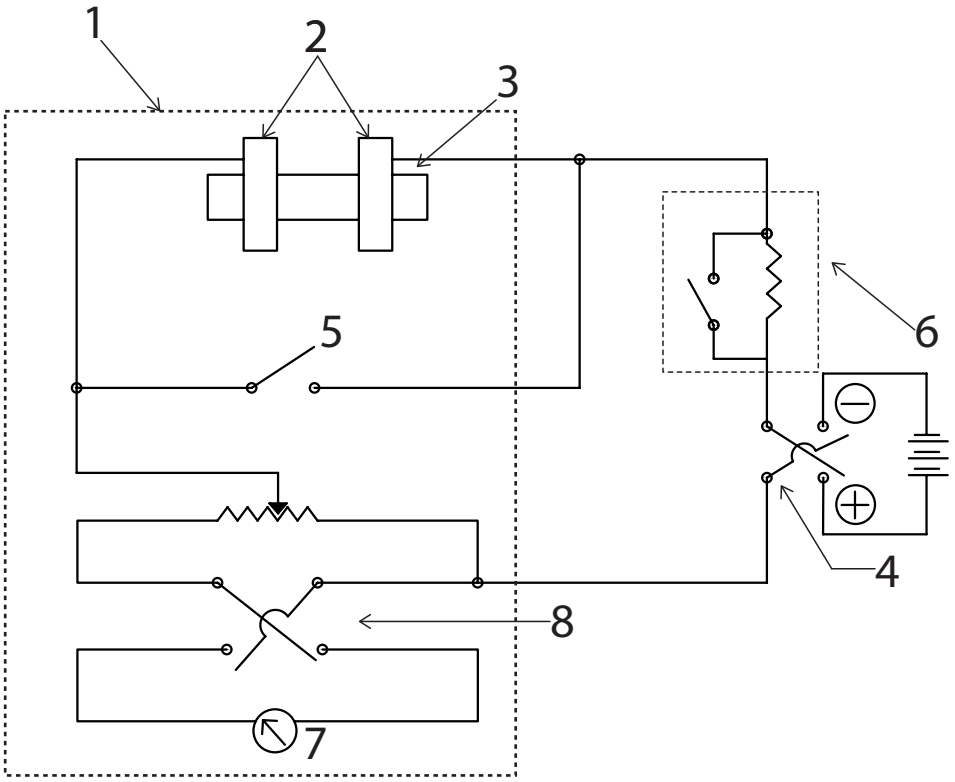


Figure 7 — Test specimen for direct-current insulation resistance test



Key

1 guard
2 electrode
3 test specimen
4 power supply polarity change-over switch
5 universal shunt
6 reference resistance (R_S)
7 galvanometer
8 galvanometer polarity change-over switch

Figure 8 — Direct-current insulation resistance measuring device

The direct-current insulation resistance shall be calculated with the obtained test result using Formula (3).

$$R = R_s \frac{S_1 \times \theta_1}{S_2 \times \theta_2} \tag{3}$$

where

R is the direct-current insulation resistance (MΩ);

R_s is the reference resistance (MΩ);

S_1 is the magnification of universal shunt at the time of measuring using the reference resistance R_s (mm);

θ_1 is the deflection of galvanometer at the time of measuring using the reference resistance R_s (mm);

S_2 is the magnification of universal shunt at the time of connecting the test specimen (mm);

θ_2 is the deflection of galvanometer at the time of connecting the test specimen (mm).

4.9 Water absorption

The water absorption test shall be conducted according to ISO 62, method 1.

The test specimen with the dimensions 30 mm × 30 mm × 100 mm shall be prepared and the longitudinal axis shall be fixed in accordance with the longitudinal direction of the test specimen.

4.10 Mass density

The mass density of raw material shall be measured at (23 ± 5) °C. Based on the result of test, the mass density shall be determined according to Formula (4). In alternative, the mass density shall be determined according to ISO 1183-1.

$$\rho = \frac{m}{V} \tag{4}$$

where

ρ is the mass density (g/cm^3);

m is the mass (g);

V is the measured volume (cm^3).

4.11 Linear expansion coefficient

The linear expansion test shall be conducted using the following method.

The test specimen with the dimensions 10 mm × 10 mm × 120 mm shall be prepared and heated from temperatures of –30 °C to 60 °C in a period of 1 h, and the linear extension of the test specimen shall be measured to an accuracy of 0,01 mm with the micrometer callipers specified in ISO 3611.

The linear expansion coefficient shall be determined using Formula (5). In alternative, the coefficient of linear thermal expansion shall be determined according to ISO 11359-2.

$$\alpha = \frac{l}{L(t_2 - t_1)} \tag{5}$$

where

α is the linear expansion coefficient;

l is the expansion (mm);

L is the length of the test specimen before heating (mm);

t_2 is the ambient temperature at the time of measurement of expansion, i.e. 60 °C (°C);

t_1 is the ambient temperature before heat-up, i.e. −30 °C (°C).

The test method should be established and implemented based upon an agreement between the interested parties.

4.12 Flame resistance

4.12.1 Option 1

The flame resistance test shall be conducted in accordance with IEC 60695-11-20:2003, 8.3. The results shall be judged based on the occurrence of flame penetration in the test specimen. To identify non-combustibility, the flame shall not penetrate any of the five test specimens.

4.12.2 Option 2

The flame resistance test shall be conducted with reference to IEC 60695-11-20:2003, 8.3, except the condition that the thickness of the test specimen shall be minimum among those normally supplied. The test result shall be judged based on the complete burnout of the test specimen and the time of after-flame and after-glow on the test specimen. To identify non-combustibility, the test specimen shall not burn completely and the time of after-flame and after-glow shall not exceed 60 min on any of the five specimens.

4.13 Weathering resistance

4.13.1 Reference method

The resistance capacity of material exposed to ageing effects shall be assessed in accordance with Annex A. The information shall be specified on the changes of mechanical properties of the test specimen after exposure to artificial ageing, the exposure to natural ageing, and thermal ageing.

When the material is tested in artificial weathering specified in A.4, the minimum duration of exposure shall depend on the material, test apparatus, and test conditions. The requirement of weather resistance shall be agreed between the interested parties.

In absence of such an agreement, the minimum duration of exposure shall be 10 000 h. This duration corresponds to approximately 10 years of ageing effect in natural conditions under a Mediterranean climate, e.g. the southern areas of France.

The changes of mechanical values shall be analysed at least four times during the test, e.g. 2 000 h, 4 000 h, 6 000 h, and 8 000 h, to investigate that the degradation is limited only to the surface layer and that the test specimen still keeps sufficient capacities for track operation in the degradation of cyclic and reproducible properties.

For the exposure to artificial weathering, the mechanical properties of the test specimen shall be determined in accordance with the method specified in Table A.1, as relevant.

For the exposure to natural ageing, the mechanical properties of the test specimen shall be determined in accordance with the method specified in Table A.1, as relevant.

For the exposure to thermal ageing whose activation energy and duration are defined in Table A.2, the mechanical properties of the test specimen shall be determined in accordance with the method specified in Table A.1, as relevant.

4.13.2 Alternative method

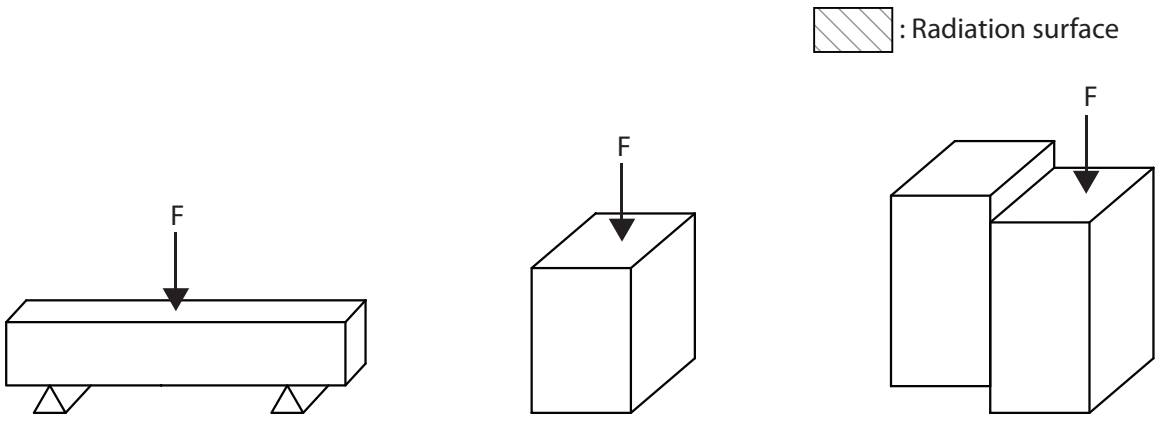
The weathering resistance test shall be conducted by exposure either to carbon-arc lamps in accordance with ISO 4892-4 or to xenon-arc lamps in accordance with ISO 4892-2. The test specimens shall have the same dimensions as those shown in 4.2, 4.3, and 4.6.

When the test specimens are fixed on the equipment for testing, the direction of the irradiation relative to the test specimens shall be as shown in Figure 9.

In the case of an exposure to arc-carbon lamps, the room temperature shall be (36 ± 5) °C, and the time of irradiation shall be the 120 min cycle consisting of 102 min for ultraviolet irradiation and 18 min for ultraviolet irradiation and spray. The duration of irradiation shall be 5 000 h.

In the case of an exposure to xenon-arc lamps, the exposure shall be conducted according to method A, cycle 1, as defined in ISO 4892-2 and the duration of irradiation shall be 3 300 h.

After the irradiation, the bending strength and flexural modulus, determined according to the test arrangement as shown in Figure 9 a), the longitudinal compressive strength, determined according to the test arrangement as shown in Figure 9 b), and the adhesive shear strength, determined according to the test arrangement as shown in Figure 9 c) on the test specimen, shall be measured respectively to check if every test specimen satisfies the requirement as defined in 3.4.



a) Test specimen for bending strength and Young modulus in flexure

b) Test specimen for longitudinal compressive strength

c) Test specimen for adhesive shear strength

Figure 9 — Directions of UV radiations

4.14 Sleeper dimensions

4.14.1 General

For measurement of the dimensions, the plastic sleeper shall be placed horizontally. The measurement shall be conducted using a steel tape measure, metal rule, or vernier calliper as specified in ISO 13385-1 and ISO 13385-2, or using micrometer callipers as specified in ISO 3611, using the following methods.

4.14.2 Measurement of dimensions

For the measurement of the dimensions, the test specimen shall be placed horizontally on a smooth surface and the dimension of each side shall be measured as shown in Figure 10. The average values of thickness and width shall be determined by averaging the measurements at the central point and both ends of the specimen parallel to the length. The length shall be calculated on the average values measured at the central point and both ends of the test specimen in parallel to the width.

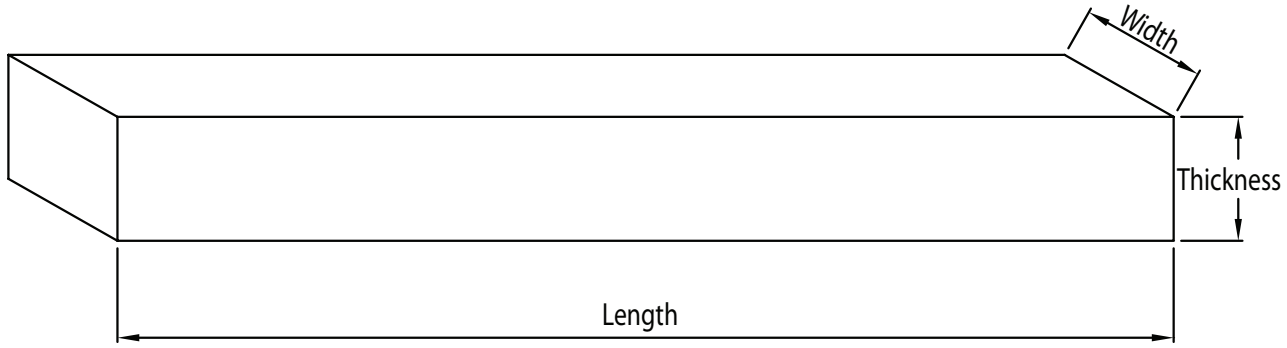
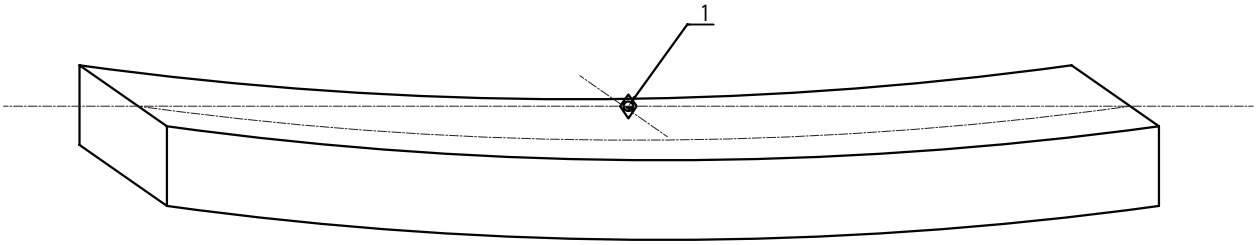


Figure 10 — Dimensions of a sleeper

4.14.3 Measurement of camber

For the measurement of camber, the test specimen shall first be placed horizontally on a smooth surface. A string shall be stretched horizontally between the central points on both ends on the top-face of the test specimen. The camber at the deepest position shall be measured between the top-face of the test specimen and string as shown in Figure 11. The tolerance of camber shall be calculated by dividing the measured camber by the length of the test specimen.



Key

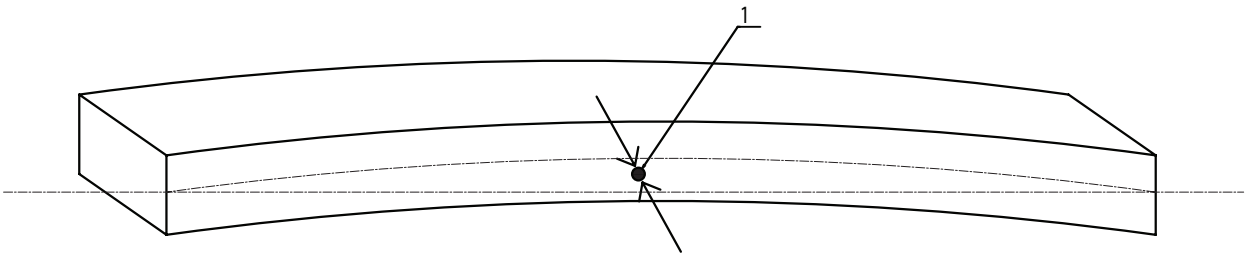
1 camber

Figure 11 — Camber of a sleeper

4.14.4 Measurement of bend

For the measurement of bend, the test specimen shall be placed horizontally on a smooth surface. A string shall be stretched horizontally between the central points of both ends on the side face of the test

specimen, and the maximum bend shall be measured as shown in Figure 12. The tolerance of bend shall be calculated by dividing the amount of bend by the length of the test specimen.



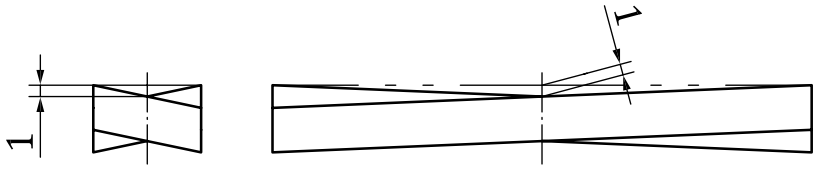
Key

1 amount of bend

Figure 12 — Bend of a sleeper

4.14.5 Measurement of torsion

For the measurement of torsion, the test specimen shall be placed on a smooth surface. A string shall be stretched horizontally along the top face on the diagonal line. The difference between the string and the top face at the highest position shall be measured as shown in Figure 13. The tolerance of torsion shall be calculated by dividing the amount of torsion by the length of the test specimen.



Key

1 amount of torsion

Figure 13 — Measurement method of torsion

5 Inspection

The characteristics to be inspected, the frequencies of testing, the numbers of tests to be performed, etc. shall be agreed on by the interested parties.

Annex A
(normative)

Methodology for assessing material ageing

A.1 General

This annex provides a methodology to assess the ageing of plastic/composite sleepers. It is applicable to composite materials made from either fibre-reinforced thermoplastic matrix or fibre-reinforced thermosetting matrix.

A.2 Principle

A polymer composite sleeper is submitted, in a first step, to degradation due to exposure to sunlight, especially UV light. This surface photo-oxidation will cause changes not only in visual appearance that are *a priori* acceptable, but also physical surface degradation caused by chalking, progressive erosion, and microcracking that, together, can lead to a loss of mechanical properties.

Accelerated ageing tests under artificial laboratory light sources shall be conducted making sure that the tests are performed at representative levels of stress and that the method is able to assess an acceleration factor. To meet these requirements, the chemical changes of the systems (as recommended by ISO 10640) should factor in first. Then the resulting physical changes are determined. In case of degradation by progressive erosion, losses of oxidized material shall be as low as possible. This requires an optimization of the light stabilization of the surface layers.

Long-term thermal ageing affects both the surface layers and the deep layers of sleepers. The level of thermal stress to which the sleepers is submitted depends not only on environmental temperature but also especially on their temperature increase driven by photothermal effect and the absorption of visible and IR light. Thermal oxidation affects not only the surface but also the deep layers of the sleepers, which means that ageing has consequences that can be detrimental to their function.

The stability to hydrolysis also needs to be evaluated on not only new sleepers but also on aged sleepers. Cyclic tests which combine heat/cold/humidity periods can be used to assess the consequences of differential expansion on the mechanical properties of the sleepers, especially in the parts involving the inserts.

Since in-use pollution by maintenance products or potential environmental pollutants is able to affect the material's properties, these substances need to be identified and chemical resistance tests can be developed as necessary.

A.3 Material identification and characterization

The material composition from which the sleeper is made shall be identified and characterized before ageing by the following:

a) infrared spectroscopy analysis;

b) the determination of the Vicat softening temperature (VST) according to ISO 306, the temperature of deflection under load according to ISO 75 (all parts), or the glass transition temperature by differential scanning calorimetry (DSC) according to ISO 11357-2, depending on the nature of the matrix polymer. Where possible, the oxidation induction time (OIT) can be also determined;

c) the type and content of filler and/or reinforcement.

This list is not exhaustive and other methods can be used for the material characterization if they are relevant for the material in consideration, provided they are documented.

In cases of a sleeper of non-homogeneous structure, the manufacturer shall document the structure of the sleeper, and each individual material layer shall be characterized using appropriate methods as stated in A.4.2.3.

A.4 Accelerated artificial ageing

A.4.1 Purpose of the tests

The ageing of polymers during the exposure to artificial weathering shall be assessed by monitoring:

a) the chemical changes in the material by Fourier transform infrared (FTIR) spectroscopy, according to the methodology provided by ISO 10640. Chemical changes shall be the same in the artificial ageing tests as in natural conditions for a low rate of degradation;

b) the macroscopic properties of the material resulting from the chemical degradations of the material which dictate the service life of the sleeper.

Surface erosion and the resulting surface topology should be closely monitored, as these parameters are the source of change in the mechanical properties which dictate the service life.

The acceleration factor of the laboratory accelerated tests shall be estimated based on comparison with the tests conducted under natural conditions over the first few years.

A.4.2 Method of laboratory exposure

A.4.2.1 General

Laboratory exposure tests shall be performed by exposure to xenon-arc lamps in accordance with ISO 4892-2, method A, cycle 1.

The laboratory test conditions shall be inspected according to the method given in ISO/TR 19032, using a polyethylene reference specimens (PERS) film.

Other light sources (e.g. medium pressure mercury lamps) can be used provided that a correlation between the test results obtained with these light sources and those obtained after an artificial exposure according to ISO 4892-1 and natural exposure can be demonstrated.

NOTE 1 The processes of photochemical degradation of polymers are activated by the temperature (a thermal activation energy of the processes is existing) and, consequently, the actual temperature of the test specimen has a great influence on the speed of degradation.

NOTE 2 Water can extract and wash additives, hydrolyse, or erode the oxidation products of the polymer, as well as stress the photocatalytic effect of some photoconductive pigments. The roles of water being multiple, it is advisable to make sure that its application in the test conditions in laboratory do not lead to non-reproducible effects in reality.

The minimum duration of exposure is specified in 4.13.1.

Reproducibility of the surface changes should be demonstrated in order to anticipate the changes over 50 years.

A.4.2.2 Test specimens

A study shall be conducted on how the test specimens are to be designed and produced (e.g. by cutting a sample from the sleeper, by moulding). In particular, care shall be taken to ensure that the surface condition of the test specimens is equivalent to that of the sleeper to be tested.

The test specimens shall be made useable for monitoring

— chemical changes by early-phase FTIR spectrometry,

— macroscopic surface changes, particularly changes in erosion and topology, and

— changes in mechanical properties.

The number of test specimens depends on the type of characterization to be carried out.

Frequency of inspections shall be optimized to fit the adopted test durations.

Sampling shall allow predicting the degradation process.

The thickness of the test specimens depends on the type of material and the structure of the sleeper to be tested.

A.4.2.3 Changes in properties

A.4.2.4.1 Monitor chemical changes in the test specimen surface *via* an FTIR spectroscopy analysis in early phase.

A.4.2.4.2 Monitor erosion and topology changes of the test specimen surface with assessment of microcracking using appropriate metrology and/or optics-based methods.

A.4.2.4.3 Monitor changes in mechanical properties to assess the consequences of test specimen surface degradation.

Depending on the constitutive material and structure of the sleeper to be tested, determine the mechanical test specimen property or properties that need to be assessed, from the following list:

— flexural properties: flexural stress at rupture or flexural strength, flexural modulus of elasticity, flexural deformation at rupture;

NOTE Flexural tests are tests that characterize a degree of damage and the acceptable limit. They are not designed to simulate sleeper response to mechanical stresses.

— tensile properties: tensile modulus of elasticity, tensile strength;

— compressive properties: compressive strength;

— other properties specific to the material [e.g. the tensile-impact strength for composites based on unplasticized poly(vinyl chloride)].

The test methods to be applied and the characteristics to be assessed shall be selected from Table A.1 depending on the constitutive material of the sleeper.

Table A.1 — Test methods for assessing mechanical properties

Material	Test method	Characteristics to be assessed
Thermoplastic matrix materials	ISO 178	Flexural stress at rupture Flexural strength Flexural modulus of elasticity Flexural deformation at rupture
	ISO 527-2	Tensile modulus of elasticity Tensile strength
	ISO 8256[a]	Mean values Individual values
Materials based on long fibre-reinforced (fibre length under 7,5 mm) thermosetting resins	ISO 178	Flexural stress at rupture Flexural strength Flexural modulus of elasticity Flexural deformation at rupture
	ISO 527-4	Tensile modulus of elasticity Tensile strength
Materials based on long fibre-reinforced (fibre length over 7,5 mm) thermosetting resins	ISO 14125	Flexural strength Flexural modulus of elasticity
	ISO 527-4	Tensile modulus of elasticity Tensile strength

[a] For composites made from unplasticized poly(vinyl chloride) only.

Test specimen characterization tests should be performed at frequencies compatible with the degree of development of the chemical changes and changes of surface properties of the material.

A.5 Exposure to natural ageing

A.5.1 General

Natural ageing exposure tests shall be carried out according to method A specified in ISO 877-2:2009, preferably on a natural ageing site located in a Mediterranean climate according to ISO 877-1:2009, Table A.1.

Additional tests can be carried out on a site located in a humid tropical zone in order to gain test results that can be processed in a shorter timeframe, making it possible to establish by comparison long-term extrapolations of the properties. However, in addition to the global solar irradiation exposure and the temperature of the exposure site, the high relative humidity that is liable to promote phenomena linked to microorganism growth should be taken into account.

NOTE 1 Assessment of the solar irradiation conditions should refer to Reference [3].

NOTE 2 For example, natural exposure at tilt angle of 45° to the horizontal, towards the south, for one year in the south of France equates to a total solar irradiance exposure of 6,6 GJ/m^2 and a mean air temperature of 15,5 °C.

Take quarterly samples in summer months and half-yearly samples in winter months to produce test specimens intended for quantifying early-phase chemical changes.

Take yearly samples over a period of five years or more to produce test specimens intended for monitoring surface degradation and mechanical properties.

A.5.2 Test specimens

Use test specimens of the same type as those used for the artificial ageing tests (see A.4.2.2) and/or test specimens cut from the sleeper(s) exposed to natural ageing.

NOTE Complete sleepers can also be exposed to natural ageing in order to validate the results observed on smaller-sized test specimens.

A.5.3 Changes in properties

The material properties monitoring protocol defined under A.4.2.3 for the artificial ageing tests also applies to the natural ageing exposure tests.

A.6 Thermal ageing

A.6.1 Principle

The thermal stress to which the core of the sleepers is submitted is primarily due to the photothermal effect of visible and infrared light in the solar radiation spectrum.

Thermal ageing shall be assessed based on the principles set out in ISO 2578.

Accelerated thermal ageing of the test material is achieved by subjecting it to higher temperatures than those found in normal service but keeping a constant mechanism for oxidation.

Knowing the thermal activation energy of the material in relation to changes in oxidation, it becomes possible to make projections on the results of accelerated ageing tests for changes in oxidation levels under service conditions.

If the thermal activation energy of the sleeper constitutive material to be tested is unknown, it should be referred to A.6.4.

Thermal ageing shall be assessed by monitoring the mechanical properties of the materials and, eventually, by monitoring of the chemical change (such as consumption of protection additives, kinetic analysis of the chemical degradation).

A preliminary test can be performed on test specimens optimized for these thermal ageing tests, after which the test can be extended to test specimens consisting of half-sleepers of full sleepers.

A.6.2 Ageing in a climate chamber for testing at 70 °C

Test specimens representative of the constitutive material of the sleeper to be tested shall be placed in a ventilated chamber climate-controlled at, for example, 70 °C ± 2 °C with a relative humidity of 30 % ± 5 %. The test duration is defined in Table A.2 according to thermal activation energy, and corresponds to a lifetime of 50 years.

Table A.2 — Exposure duration according to thermal activation energy

Thermal activation energy E_Δ KJ/mol	**Duration of exposure** h
50	21 000
60	11 000
70	5 500
80	2 800

It is possible to extrapolate at 50 years on the basis of thermal ageing testing corresponding to 30 years provided it is documented.

A.6.3 Changes in mechanical properties

Monitor changes in the mechanical properties of the test specimens as specified in A.4.2.4.3.

A.6.4 Determination of thermal activation energy for the oxidative degradation of a material

If the thermal activation energy of the constitutive material of the sleeper to be tested is unknown, the material is thermally aged at at least three (and generally four) temperatures, i.e.

— T_1, the lowest temperature, approximately 20 °C to 30 °C above the average temperature in service (it shall be at least equal to 60 °C),

— T_2, an intermediate temperature between T_1 and T_3, and

— T_3, the maximum temperature, allowing for the limits of the material under study and the stability of the primary oxidation products.

The material shall not undergo any physical phase transition, such as glass transition or melting, within this temperature interval.

Chemical ageing of the material is monitored by infrared (IR) spectrometry, while physical ageing shall be concurrently monitored *via* the mechanical tests defined in Table A.1, in order to determine the period during which degradation is induced, and to find a relationship (at least an approximation) between oxidation changes and the changes in physical properties implied in sleeper lifetime.

A material fits the Arrhenius model when the log plot of the quantity D, used to measure degradation, is proportional to $1/T$, i.e. it satisfies Formula (A.1):

$$\ln[D] = \left[\frac{E_T}{R}\right] \cdot \left[\frac{1}{T}\right] \tag{A.1}$$

where

D is the quantity being monitored;

E_T is the apparent global thermal activation energy, in kilojoules per mole;

R is the ideal gas constant, i.e. 8,314 472 $J \cdot mol^{-1} \cdot K^{-1}$;

T is the temperature of the material, in Kelvin.

The slope of the plot can be used to determine thermal activation energy E_Δ.

The projection for sleeper service use can be extrapolated by calculating the ratios of the constants of velocity to any temperature T_X and to a reference temperature T_R using Formula (A.2):

$$\frac{K_X}{K_R} = \exp\left[\frac{E_\Delta}{R}\left(\frac{1}{T_R} - \frac{1}{T_X}\right)\right] \quad \text{(A.2)}$$

where

K_X is the constant of velocity at temperature T_X;

K_R is the constant of velocity at temperature T_R;

E_Δ is the thermal activation energy, in kilojoules per mole;

R is the ideal gas constant, i.e. 8,314 472 $J \cdot mol^{-1} \cdot K^{-1}$;

T_R is the reference temperature, in Kelvin;

T_X is the temperature of the sleeper, in Kelvin.

At this stage in measurement processing, it is necessary to plot the temperature-service life profile of the sleeper.

EXAMPLE Temperature-service life profile, expressed as a percentage of sleeper service life:

25 % at 10 °C; 45 % at 20 °C; 12 % at 30 °C; 6 % at 40 °C; 5 % at 50 °C; 5 % at 60 °C; 2 % at 70 °C.

The constants of velocity weighted by relative service periods at the different temperature levels allow for estimate change in the most critical property, and, thus, the service lifetime, or conversely, for an expected service lifetime of 50 years with the temperature-service life profile proposed and for the most critical property, to determine the duration of the accelerated ageing test at a selected temperature.

Table A.3 gives exposure temperatures and durations according to thermal activation energy.

Table A.3 — Test temperatures and durations according to thermal activation energy

Thermal activation energy E_Δ KJ/mol	**Exposure temperature and duration for a 50 year expected service life**
50	21 000 h at 70 °C
60	11 000 h at 70 °C
70	25 400 h at 50 °C 17 000 h at 55 °C 11 600 h at 60 °C 5 500 h at 70 °C 2 800 h at 80 °C 1 500 h at 90 °C
80	6 500 h at 60 °C 2 800 h at 70 °C

If the thermal activation energy, E_Δ, cannot be determined, it remains possible to use 70 KJ/mol as a default value roughly corresponding to the empirical "factor 2 for every 10 °C" rule, although it can introduce significant error into the projection.

Preliminary studies can be developed to determine the thermal activation energy, E_Δ, of the material under study, for each property selected.

Annex B
(informative)

Examples of typical sleepers

B.1 General

This Annex gives examples of typical plastic and reinforced materials for which proven uses of sleepers made from these materials exist at the date of publication of this part of ISO 12856. The same materials, eventually with different dimensions and spacing, can also be used for other different types of railways and use conditions.

B.2 Conditions of use and definitions of material examples

— Material type A: equivalent to tropical hardwood sleepers for track without ballast and special track work, up to 20 t per axle for a speed of 130 km/h and 14 t per axle for a speed of 300 km/h.

— Material type B: equivalent to wooden sleeper for UIC 5/6 track categories, lines up to 22,5 t per axle for a speed of 160 km/h.

— Material type C: equivalent to hardwood sleeper for heavy-haul track up to 35 t per axle for a speed of 80 km/h.

B.3 Normal dimension of plastic/composite sleeper

Table B.1 gives standard dimensions for railway sleepers of types A, B, and C. It gives typical dimensions for each type and, therefore, spacing should be adjusted according to the manufacturer's and users' requests.

Table B.1 — Sleeper dimensions

Dimensions in millimetres

Dimensions	Sleeper dimensions		
	Type A	Type B	Type C
Thickness	140 to 250	150	178
Width	200 to 300	250	229
Length	2 000 to 8 000	2 600	2 600 to 2 700

B.4 Dimensional tolerances

The dimensional tolerances shall be as specified in Table B.2 when the measurement is conducted according to 4.14.

Table B.2 — Dimensional tolerances

Dimensional characteristic	Unit	Tolerances			Test method		
		Type A	Type B	Type C	Type A	Type B	Type C
Thickness	mm	±2	±2	±3	4.14.2		
Width	mm	±3	±3	±6			
Length	mm	±5	±10	±10			
Camber and bend	—	≤2/1 000	—		4.14.3 and 4.14.4	—	
Torsion	—	≤1/1 000	—		4.14.5	—	

B.5 Requirements

B.5.1 Physical, mechanical, and electrical characteristics

When the sleepers and the test specimens/parts are tested in accordance with the test methods as specified in 4.1 to 4.13 using the indicated parameters, the sleepers shall have the characteristics conforming to the requirements given in Table B.3 and Table B.4.

Table B.3 — Physical, mechanical, and electrical characteristics

Material properties		Unit	Requirements			Test method		
			Type A	Type B	Type C	Type A	Type B	Type C
Material strength	Bending strength	MPa	≥28[a]	≥18	≥13,8	4.2		
	Flexural modulus	MPa	≥6 000	≥2 500	≥1 170			
	Longitudinal compression strength	N/mm^2	≥40	≥8	—[b]	4.3		—[b]
	Lateral compression strength	N/mm^2	—[b]	≥8	≥6,2	—[b]	4.4	
	Shear strength	N/mm^2	≥7	≥4,5	—[b]	4.5		—[b]
	Adhesive shear strength	N/mm^2	≥7 Base-material breakage	—[c]	—[c]	4.6	—[c]	
Electrical characteristics	Alternating-current breakdown voltage	kV	≥20	≥20	—[c]	4.7		—[b]
	Direct-current insulation resistance	Ω	$\geq 1 \times 10^{10}$	$\geq 2 \times 10^{4}$	$\geq 2 \times 10^{4}$	4.8		
Water absorption		%[d]	≤2	≤2	—[b]	4.9		—[b]
Mass density		g/cm^3	≥0,64	≥0,8	≥0,8	4.10		
Linear expansion coefficient		K^{-1}	$\leq 5 \times 10^{-5}$	$\leq 6 \times 10^{-5}$	$\leq 1{,}35 \times 10^{-4}$	4.11		

a This is based on a minimum functional safety factor but a higher value might be required.

b There can remain blanks in the table if the requirements need not necessarily be established. However, for the purpose of railway operation, the requirements can be defined as a necessity through agreement between the manufacturers and purchasers.

c This can remain blank because there is no part that uses adhesives and hence no need to establish the requirement.

d Percentage expressed in mass fraction.

Table B.4 — Temperature-dependent mechanical properties

Material properties		Unit	Test conditions and requirements	Test method
Material strength	Bending strength	%[a]	In air for 24 h Test temperatures[b]: −30 °C: ≥ 100 60 °C: ≥ 70	4.2
	Flexural modulus	%[a]		
	Longitudinal compression strength	%[a]		4.3
	Shear strength	%[a]		4.5

[a] Percentages indicate the strength retention in comparison with the values determined at an ambient temperature.

[b] Test temperatures can vary in the conditions where sleepers are used (tunnels, extreme weather conditions, excessively exposed locations).

B.5.2 Weathering resistance

When the resistance capacity of material exposed to ageing effects are assessed in accordance with 4.13.1, it is recommended that the changes of the mechanical properties of the sleepers are less than or equal to 20 % of the initial values.

When the resistance capacity of material exposed to ageing effects are assessed in accordance with 4.13.2, it is recommended that the changes of the mechanical properties of the sleepers are less than or equal to 30 % of the initial values.

Bibliography

[1] ISO 179-1, *Plastics — Determination of Charpy impact properties — Part 1: Non-instrumented impact test*

[2] ISO 2818, *Plastics — Preparation of test specimens by machining*

[3] WMO. No. 8: *Guide to meteorological instruments and methods of observation*. World Meteorological Organization, Seventh Edition, 2008

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