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Fibre-reinforced plastic composites — Determination of plain-pin bearing strength

Composites plastiques renforcés de fibres — Détermination de la résistance au matage au moyen d'une goupille ordinaire

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Contents

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 12815 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

Introduction

In preparing this harmonized version, reference was made to similar methods, such as prEN 6037 and ASTM D 5961, harmonization with open-hole tests has been achieved where relevant (e.g. specimen and hole size). The method is applicable to all current and future fibre-reinforced plastic composites meeting the requirements of this International Standard.

The method described in this International Standard uses the maximum load to define the plain-pin laminate bearing strength. This point is well-defined and has been shown to be at a similar level to the less easily defined, initial failure in the similar "torqued bolt" test(s) (see below). In the torqued bolt test, the load can increase after the bearing failure (up to x 2), as the failed material is jammed against the bolt, washers and loading jigs. The property determined applies only to the laminate lay-up tested.

The strength properties of "bolted" joints are dependent on the actual conditions involved for the joint being assessed. This includes initial bolt torque (including any load lost in bolt threads), effect of relaxation due to visco-elastic effects, effect of hot/wet conditioning, washer size/over-size, bolt material/rivet details and chamfer depth/plate thickness. It is recommended that additional tests to the plain-pin test be conducted for the actual joint conditions of interest in the applications, as no standardized configuration can represent all these variations. ASTM D 5961, *Standard test method for bearing response of polymer matrix composite laminates,* can be used as guidance on bolted joint tests.

Fibre-reinforced plastic composites — Determination of plain-pin bearing strength

1 Scope

This International Standard specifies a procedure for determining the plain-pin bearing strength of fibre-reinforced plastic composites.

The method described in this International Standard is applicable to fibre-reinforced plastic composites with either thermoset or thermoplastic matrices.

2 Normative references

The following referenced documents are indispensable for the application 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 291, *Plastics — Standard atmospheres for conditioning and testing*

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

ISO 472, *Plastics — Vocabulary*

ISO 1268 (all parts), *Fibre-reinforced plastics — Methods of producing test plates*

ISO 2602, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*

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

ISO 5893, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Specification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472 and the following apply.

3.1
plain-pin bearing strength
σ_p
stress obtained by dividing the maximum load by the projected cross-sectional area of the pin contact area with the specimen (i.e. d x t)

Note 1 to entry: The result is expressed in megapascals, MPa.

3.2
specimen coordinate axes
coordinate axes for the material under test, the direction parallel to the plate longitudinal axis being defined as the "1" direction, the direction perpendicular to them as the "2" direction and, the direction "3" being perpendicular to the plate (i.e. the through-thickness direction)
[SOURCE: ISO 527-4:1997, Clause 4.8]

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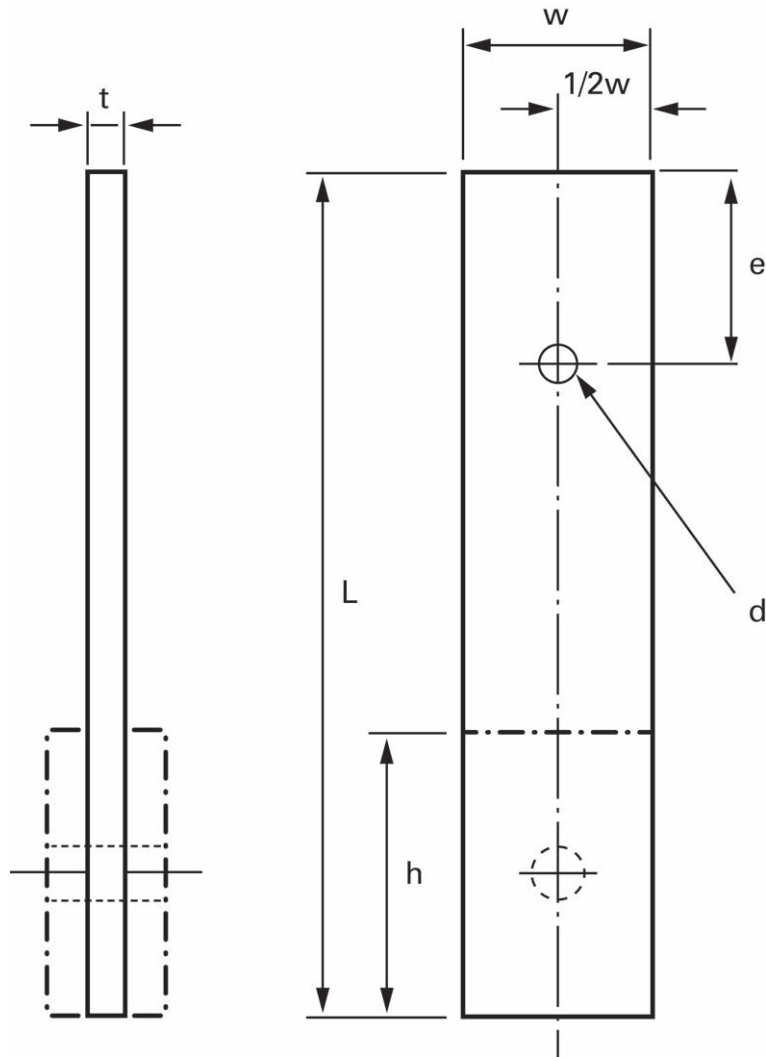
Key

t thickness

w specimen width

L specimen length

e distance from end of specimen

h   length of tabbing (if used)

d pin/hole diameter

Figure 1 — Test specimen for determination of plain-pin bearing strength

4   Principle

A test specimen consisting of a strip of rectangular cross-section with a plain hole, centrally positioned with respect to the width, is loaded in tension by a clearance fit metallic plain-pin. The maximum load sustained by the specimen is used to determine the plain-pin bearing strength, based on the projected area of the pin in contact with the specimen. The test measures a material plain-pin bearing strength under these loading conditions, rather than a load to fail a bolted joint, for the laminate lay-up tested.

5 Apparatus

5.1 Test machine.

5.1.1 General, test machine conforming to ISO 5893 as appropriate to the requirements given in 5.1.2 to 5.1.3.

5.1.2 Speed of testing, v, shall be kept constant according to ISO 5893.

5.1.3 Indicator for load, such that the error in the indicated force is less than ±1 % of the full scale (see ISO 5893).

5.2 Micrometer, or equivalent, capable of reading to 0,01 mm, or less, and suitable for measuring the thickness, t and width, w of the test specimen; and the pin/hole diameter, d and position. The micrometer shall have faces appropriate to the surface being measured (i.e. flat faces for flat, polished surfaces and hemispherical faces for irregular surfaces).

5.3 Loading jig and pin, the plain-pin is loaded by a double-shear metal plate assembly, as shown in Figure 2. The loading jig shall include clearance, c, of at least 0.5 mm on both sides of the specimen and shall not distort under the applied load. The pin should be manufactured in a hardened steel. The loading pin shall similarly not distort during the test and should be an clearance fit in the hole in the specimen, unless specified otherwise. The loading pin shall have a diameter of 6 mm (tolerance 0 to −0.05 mm).

NOTE   Hardened plates are acceptable as an alternative to the use of the hardened bushes shown in Figure 1.
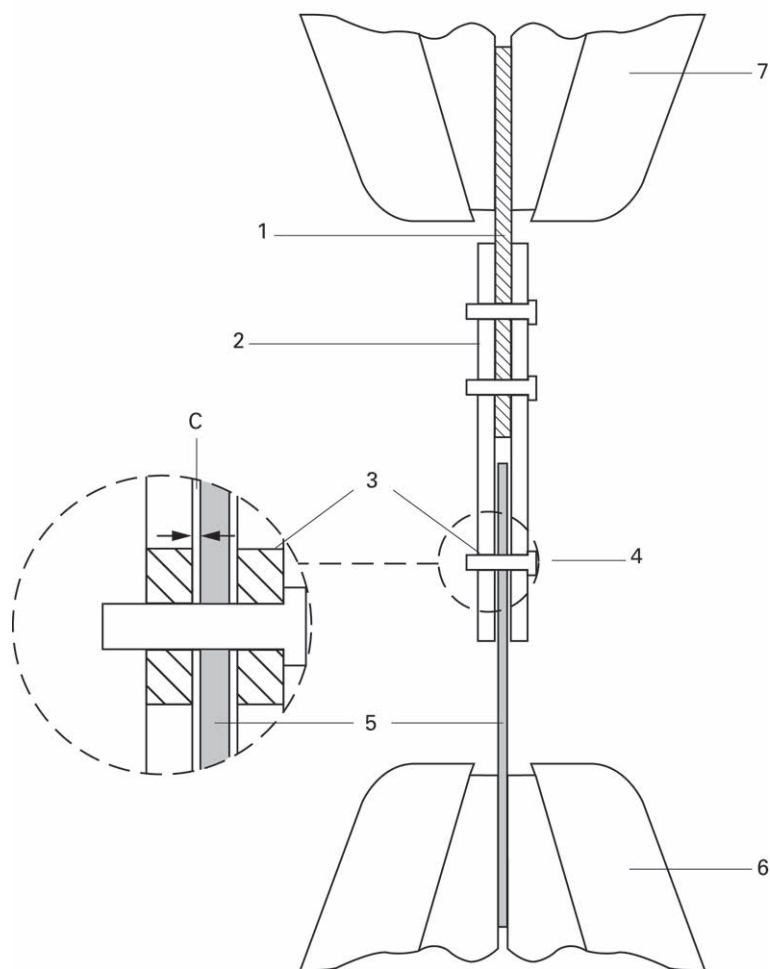
Key

1   grip plate
2   side plate
3   hardened bushes
4   hardened loading pin
5   specimen
6, 7   machine grips
c clearance = 0.5 mm (minimum)

Figure 2 — Loading plates and test arrangement

6 Test specimens

6.1 Shape and dimensions

6.1.1 Preferred specimen size

The specimen shall have a width, w, of 36 mm ± 0,5 mm and a length, L of 100 to 180 mm. In cases of dispute the specimen length shall be 180 mm. For specimen thickness reference shall be made to the international standard for the material or the appropriate part of ISO 1268 for test panel manufacture, otherwise a minimum of 4 mm shall be used for the pin hole size given in 6.1.2. The width of individual specimens shall be parallel to within 0,2 mm. The configuration of the specimen is shown in Figure 1.

A hole, 6 mm (tolerance 0 to + 0,05 mm), in diameter is machined within 0,1 mm of the specimen centre line and a distance, e, of 36 mm (i.e. 6 × the hole diameter) from the end of the coupon. Providing that an acceptable bearing failure (c.f. shear-out) is still obtained, the end distance, e, can be reduced to 18 mm.

6.1.2 Alternative specimen size

Alternative specimens shall maintain a specimen width/hole diameter and an end distance/hole diameter ratio of 6; and a plain-pin diameter/specimen thickness of 1,5.

NOTE   For existing applications, a 6,35 mm (0,25") hole at 38,1 mm (1,5") from the end of a 38,1 mm (1,5") wide coupon meets these requirements.

6.2   Preparation of specimens

6.2.1   General

A test plate shall be prepared in accordance with ISO 1268 (all parts) or another specified/agreed procedure. Individual specimens or groups of specimens shall be cut to the required size. Some parameters for machining are specified in ISO 2818. Further guidance on cutting specimens is given in Annex A of ISO 527-4.

The plate configuration shall be, if not given by the materials specification or as agreed by the interested parties, in a pseudo isotropic configuration. The 0°, x or axial direction in the plate shall be marked (see ISO 1268-4).

NOTE   For 0,125mm thick unidirectional plies, the quasi- isotropic configuration lay-up for a 4 mm thick panel is given by $[+45°, 90°, -45°, 0°]_{8S}$ (i.e. 8 repeats of the stacking unit).

6.2.2   End tab material (if required)

Providing failure does not occur at or within the grip, unbonded tabs or no tabs may be used. If tabs are used, they shall be constructed from a cross-ply or fabric glass-fibre/resin laminate, or from the material under test. The tab material thickness shall be between 0,5 mm and 2 mm thick, with a tab angle of 90° (i.e. not tapered). See ISO 527-4.

6.2.3   Application of end tabs

Bonded end tabs, if used, shall be applied to the specimen with a high elongation adhesive, as described in Annex A of ISO 527-4.

NOTE   A similar procedure can be used for individual specimens or for a group of specimens.

6.2.4   Machining the test specimens

The test specimen shall be cut and the hole drilled without causing damage.

6.3   Checking the test specimens

The specimens shall be flat and free of twist. The surfaces and edges shall be free from cracks, scratches, pits, sink marks and flashes. The drilled hole should not be damaged. The specimens shall be checked for conformity to these requirements by visual observation against straight-edges, squares and flat plates, and by measuring with micrometer callipers. Specimens showing measurable or observable departure from one or more of these requirements shall be rejected or machined to the required size and shape before testing. The pin shall be a clearance fit in the hole.

7 Number of test specimens

At least five test specimens shall be tested (see 9.6 for checking valid failure modes). The number of measurements may be more than five, if greater precision of the mean value is required.

It is possible to evaluate this by means of the confidence interval (95 % probability, see ISO 2602).

8 Conditioning

Where applicable, condition the test specimen as specified in this International Standard for the material under test. In the absence of such information, the most appropriate condition from ISO 291 shall be selected, unless otherwise agreed by the interested parties.

9 Procedure

9.1 Test conditions

Where applicable, the specimen shall be tested as specified in this International Standard for the material under test. In the absence of such information, the most appropriate condition from ISO 291 shall be selected, unless otherwise agreed by the interested parties (e.g. for testing at elevated or reduced temperatures).

9.2 Specimen and pin dimensions

Measure the width of the specimen to the nearest 0,1 mm and the thickness of the test piece to the nearest 0,02 mm at the mid-point of the specimen. Measure the hole diameter to ensure it is within the required tolerance (see 5.3). Measure the pin diameter and check for roundness and any distortion. Replace the pin if it is not round or if it is distorted (e.g. should not be forced into specimen/jig).

9.3 Testing speed

Where applicable, set the speed of testing as given in this International Standard for the material being tested. In the absence of this information, the speed of testing, *v*, shall be 1 mm/min.

9.4 Data collection

Record the load continuously throughout the test.

9.5 Failure load

Record the maximum load as the failure load. Discontinue testing once the load has fallen by > 50 % from peak load.

Ensure that the thickness of the specimen under compression beneath the pin contact is not expanded by Poisson's ratio effects or damage sufficient to make contact with the loading plates before the peak load is reached. If this occurs, the clearance should be increased to avoid this contact/constraint.

9.6 Failure mode

Check and record the mode of failure.

Test specimens shall fail by compression beneath the pin. The results from test specimens that do not fail by compressive bearing beneath the pin contact area shall be discarded and new specimens tested in their place (see Figure 3 a) for acceptable bearing failure; Figures 3 b) and Figure 3 c) are unacceptable). The number of unacceptable specimen failures shall be recorded.
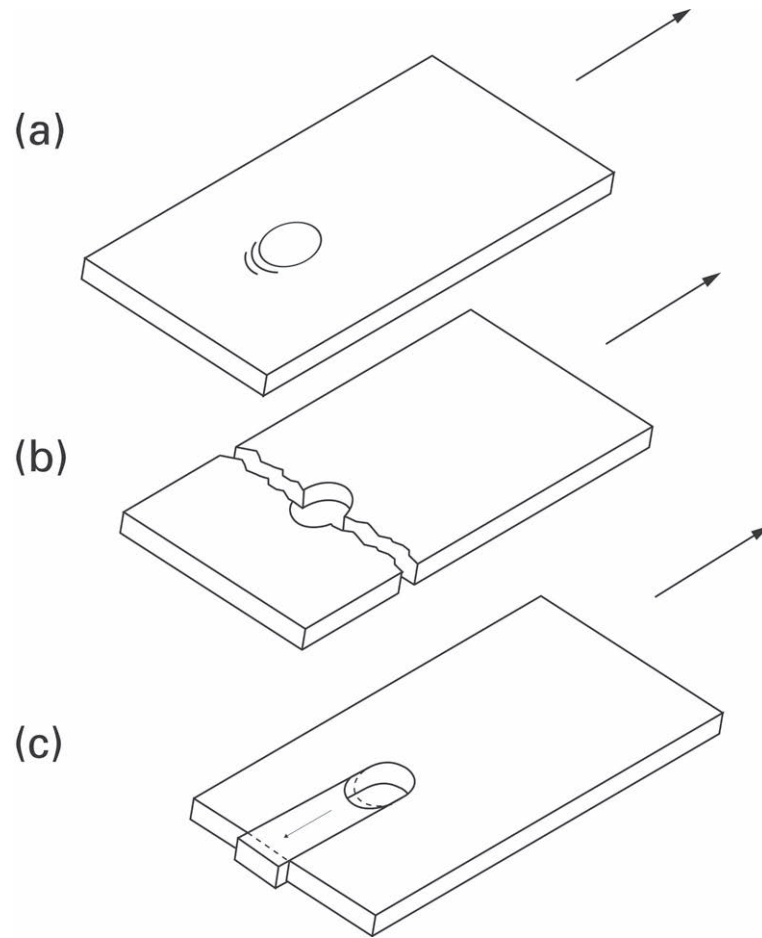
Figure 3 — Specimen failure modes (a) bearing - acceptable, (b) direct tension - unacceptable and (c) shear-out – unacceptable

10 Calculation and expression of results

Calculate the plain-pin bearing strength, σ_p, expressed in megapascals, using the following equation for clearance fitting pins:

$$\sigma_p = \frac{F}{dt}$$

where

F is the maximum load, in newtons;

d is the diameter of the loading pin, in millimeters;

t is the thickness of the test specimen, in millimeters.

Calculate the arithmetic mean of the individual determinations and, if required, the standard deviation and the 95 % confidence interval of the mean value using the procedure given in ISO 2602.

Calculate the stress to three significant figures.

11 Precision

The precision of this test method was obtained in an interlaboratory study and is summarized below. A more detailed description is given in [Annex A](#).

Table 1 — Repeatability, reproducibility and mean bearing strength for the specimens

Material	Repeatability Conditions		Reproducibility Conditions		Mean σ_p (MPa)
	S_r	r	S_R	R	
1	30,8	86,2	57,1	160,0	606,0
2	15,1	42,2	40,0	111,9	418,0
3	15,0	42,1	44,9	125,6	257,3
4	21,2	59,3	33,1	92,7	297,7

S_r - Repeatability standard deviation - The standard deviation of test results obtained under repeatability conditions.

r - Repeatability value - The value below which the absolute difference between two single test results obtained under repeatability conditions may be expected to lie with a probability of 95 %.

S_R - Reproducibility standard deviation - The standard deviation of test results obtained under reproducibility conditions.

R - Reproducibility value - The value below which the absolute difference between two single test results obtained under repeatability conditions may be expected to lie with a probability of 95 %.

NOTE Definitions taken directly from Reference.[1]

Table 2 — Repeatability and reproducibility values as a percentage of mean values for the specimens

Material	Repeatability Conditions		Reproducibility Conditions	
	S_r (%)	r (%)	S_R (%)	R (%)
1	5,1	14,2	9,4	26,4
2	3,6	10,1	9,6	26,8
3	5.8	16,4	17,5	48,8
4	7,1	19,9	11,1	31,1

Table 3 — Repeatability, reproducibility and mean plain-pin bearing strength

Materials	Repeatability Conditions		Reproducibility Conditions		Mean (MPa)
	S_r	r	S_R	R	
5	11,9	33,0	25,9	71,8	707,6
6	18,6	51,6	28,6	79,3	596,8
7	17,7	48,2	26,7	73,9	772,4
8	761,8	22,2	61,5	69,4	761,8

Table 4 — Repeatability and reproducibility values as a percentage of mean values for the specimens

Materials	Repeatability Conditions		Reproducibility Conditions	
	S_r (%)	r (%)	S_R (%)	R (%)
5	1,68	4,66	3,66	10,15
6	3,12	8,65	4,79	13,29
7	2,29	6,24	3,46	9,57
8	2,91	8,07	9,11	25,26

12 Test report

The test report shall include the following information:

a)   a reference to this International Standard;

b)   complete identification of the material tested including type, source, manufacturer's code number, form and previous history, where these are known;

c)   the date of measurement;

d)   the dimensions of the test specimens, including the hole;

e)   the size and grade of the loading pin, including the projected contact area;

f)   the method of preparing the specimens;

g)   the test conditions and conditioning procedures, if applicable;

h)   the number of specimens tested;

i)   the accuracy grading of the test machine (see ISO 5893);

j)   the individual determinations, including load-deformation diagrams, if required;

k)   the mean values of the individual determinations;

l)   the type(s) of failure obtained;

m)   a statement as to whether any test specimens have been rejected and, if so, the reasons;

n)   the standard deviations and the 95 % confidence intervals of the mean values, if required;

o)   any operation not specified in this International Standard, as well as any incident likely to have affected the results.

Annex A
(informative)

Round-Robin validation exercise for plain-pin-bearing test method

A.1 Introduction

A round-robin validation exercise has been undertaken to obtain precision data for the plain-pin bearing test method with four fibre reinforced polymer matrix composite materials representing a range of composite materials and manufacturing processes. For Materials 1 to 4, tests were undertaken by six laboratories, five of which had previously not used the method, according to the draft procedures developed by NPL (National Physical Laboratory). For Materials 5 to 8, tests were undertaken by five or six laboratories, according to the draft procedures developed by JAXA (Japan Aerospace Exploration Agency). These specimens had an edge distance from the hole, e, of 18 mm. The exercise was organized and the results were analysed according to ISO 5275 using 95 % confidence limits. Six organisations participated.

The materials chosen were:

Material 1: Quasi-isotropic carbon fibre/epoxy - autoclave moulded

Material 2: Woven glass fibre/epoxy – press moulded

Material 3: Chopped strand-mat glass fibre/polyester – hand lay-up

Material 4: Glass fibre (mixed format)/polyester – pultrusion

Material 5: Mid modulus/high strength carbon fibre/epoxy UD 24ply quasi-isotropic – autoclaved

Material 6: Mid modulus/high strength carbon fibre/epoxy plain woven fabric 12ply quasi- isotropic carbon fabric/epoxy – autoclaved

Material 7: Mid modulus/high strength carbon fibre/epoxy UD 24ply quasi isotropic – autoclaved

Material 8: Mid modulus/high strength carbon fibre/epoxy plain woven fabric 12ply quasi- isotropic carbon fabric/epoxy – autoclaved

A.2 Procedure

To reduce the variability of the results, all the specimens were prepared and machined at NPL. The specimens were cut using a water-cooled diamond faced cutting blade and a brad and spur point drill bit. The participants were asked to test six coupons per material and to send the results to NPL for collation and analysis. The analysis of the results for reproducibility and repeatability was undertaken using software written at NPL to the method described in ISO 5725, using 95 % confidence limits.

A.3 Result

The results given below are calculated using the method of ISO 5725, after removal of outliners as described in that method.

Table A.1 — Repeatability, reproducibility and mean plain-pin bearing strength

Material	Repeatability Conditions		Reproducibility Conditions		Mean σ_p (MPa)
	S_r	r	S_R	R	
1	30,8	86,2	57,1	160,0	606,0
2	15,1	42,2	40,0	111,9	418,0
3	15,0	42,1	44,9	125,6	257,3
4	21,2	59,3	33,1	92,7	297,7

S_r - Repeatability standard deviation - The standard deviation of test results obtained under repeatability conditions.

r - Repeatability value - The value below which the absolute difference between two single test results obtained under repeatability conditions may be expected to lie with a probability of 95 %.

S_R - Reproducibility standard deviation - The standard deviation of test results obtained under reproducibility conditions.

R - Reproducibility value - The value below which the absolute difference between two single test results obtained under repeatability conditions may be expected to lie with a probability of 95 %.

NOTE Definitions taken directly from Reference.[1]

Table A.2 — Repeatability and reproducibility values as a percentage of mean values for the specimens

Material	Repeatability Conditions		Reproducibility Conditions	
	S_r (%)	r (%)	S_R (%)	R (%)
1	5,1	14,2	9,4	26,4
2	3,6	10,1	9,6	26,8
3	5,8	16,4	17,5	48,8
4	7,1	19,9	11,1	31,1

Table A.3 — Repeatability, reproducibility and mean plain-pin bearing strength

Materials	Repeatability Conditions		Reproducibility Conditions		Mean
	Sr	r	S_R	R	
5	11,9	33,0	25,9	71,8	707,6
6	18,6	51,6	28.6	79,3	596,8
7	17,7	48,2	26,7	73,9	772,4
8	761,8	22,2	61,5	69,4	761,8

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Table A.4 — Repeatability and reproducibility values as a percentage of mean values for the specimens

Materials	Repeatability Conditions		Reproducibility Conditions	
	S_r (%)	r (%)	S_R (%)	R (%)
5	1,68	4,66	3,66	10,15
6	3,12	8,65	4,79	13,29
7	2,29	6,24	3,46	9,57
8	2,91	8,07	9,11	25,26

Further details on Materials 1 to 4 are given in Reference.[11]

Further details on Materials 5 to 8 are given in References[9] and.[10]

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