BRITISH STANDARD

BS EN ISO 178:2003

Incorporating Corrigendum No. 1 and Amendment No. 1

Plastics — Determination of flexural properties

The European Standard EN ISO 178:2003, with the incorporation of amendment A1:2005, has the status of a British Standard

ICS 83.080.01

British Standards

National foreword

This British Standard is the official English language version of EN ISO 178:2003 including amendment A1:2005. It is identical with ISO 178:2001, including amendment 1:2004. It supersedes BS EN ISO 178:1997 which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags [A1) (A1]. Tags indicating changes to ISO text carry the number of the amendment. For example, text altered by ISO amendment 1 is indicated in the text by [A1) (A1].

The UK participation in its preparation was entrusted to Technical Committee PRI/21, Plastics test methods, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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English version

Plastics - Determination of flexural properties (ISO 178:2001)

Plastiques - Détermination des propriétés en flexion (ISO 178:2001)

Kunststoffe - Bestimmung der Biegeeigenschaften (ISO 178:2001)

This European Standard was approved by CEN on 12 December 2002.

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Foreword

The text of ISO 178:2001 has been prepared by Technical Committee ISO/TC 61 "Plastics" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 178:2003 by Technical Committee CEN/TC 249 "Plastics", the secretariat of which is held by IBN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2003, and conflicting national standards shall be withdrawn at the latest by August 2003.

This document supersedes EN ISO 178:1996.

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Endorsement notice

The text of ISO 178:2001 has been approved by CEN as EN ISO 178:2003 without any modifications.

NOTE Normative references to International Standards are listed in Annex ZA (normative).

Foreword to Amendment A1

The text of ISO 178:2001/Amd 1:2004 has been prepared by Technical Committee ISO/TC 61 "Plastics" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 178:2003/A1:2005 by Technical Committee CEN/TC 249 "Plastics", the secretariat of which is held by IBN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 2005, and conflicting national standards shall be withdrawn at the latest by July 2005.

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Endorsement notice

The text of ISO 178:2001/Amd 1:2004 has been approved by CEN as EN ISO 178:2003/A1:2005 without any modifications.

INTERNATIONAL STANDARD

ISO 178

Fourth edition
2001-12-15

Plastics — Determination of flexural properties

Plastiques — Détermination des propriétés en flexion

Reference number
ISO 178:2001(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 178 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties*.

This fourth edition cancels and replaces the third edition (ISO 178:1993), which has been updated in the following ways:

— a method of correcting for curvature at the beginning of the stress/strain curve is given (see 9.2);

— a method of correcting for the compliance of the test machine is given (see annex A).

Annex A forms a normative part of this International Standard.

Plastics — Determination of flexural properties

1 Scope

1.1 This International Standard specifies a method for determining the flexural properties of rigid (see 3.12) and semi-rigid plastics under defined conditions. A standard test specimen is defined, but parameters are included for alternative specimen sizes for use where appropriate. A range of test speeds is included.

1.2 The method is used to investigate the flexural behaviour [1] of the test specimens and for determining the flexural strength, flexural modulus and other aspects of the flexural stress/strain relationship under the conditions defined. It applies to a freely supported beam, loaded at midspan (three-point loading test).

1.3 The method is suitable for use with the following range of materials:

— thermoplastics moulding and extrusion materials, including filled and reinforced compounds in addition to unfilled types; rigid thermoplastics sheets;

— thermosetting moulding materials, including filled and reinforced compounds; thermosetting sheets.

In agreement with ISO 10350-1 and ISO 10350-2, this International Standard applies to fibre-reinforced compounds with fibre lengths $\leqslant$ 7,5 mm prior to processing. For long-fibre-reinforced materials (laminates) with fibre lengths $>$ 7,5 mm, see reference [2] in the bibliography.

The method is not normally suitable for use with rigid cellular materials and sandwich structures containing cellular material[3, 4].

NOTE For certain types of textile-fibre-reinforced plastics, a four-point bending test is preferred. It is described in reference [2].

1.4 The method is performed using specimens which may be moulded to the specified dimensions, machined from the central portion of a standard multipurpose test specimen (see ISO 3167) or machined from finished or semi-finished products such as mouldings, or extruded or cast sheet.

1.5 The method specifies preferred dimensions for the test specimen. Tests which are carried out on specimens of different dimensions, or on specimens which are prepared under different conditions, may produce results which are not comparable. Other factors, such as the test speed and the conditioning of the specimens, can also influence the results. Especially for semi-crystalline polymers, the thickness of the oriented skin layer, which is dependent on moulding conditions and thickness, affects the flexural properties. Consequently, when comparable data are required, these factors must be carefully controlled and recorded.

1.6 Flexural properties can only be used for engineering design purposes for materials with linear stress/strain behaviour. For non-linear behaviour, the flexural properties are only nominal. The bending test should preferentially be used with brittle materials, for which tensile tests are difficult.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 291:1997, *Plastics — Standard atmospheres for conditioning and testing*

ISO 293:1986, *Plastics — Compression moulding test specimens of thermoplastic materials*

ISO 294-1:1996, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 1: General principles, and moulding of multipurpose and bar specimens*

ISO 295:—[1], *Plastics — Compression moulding of test specimens of thermosetting materials*

ISO 2602:1980, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*

ISO 2818:1994, *Plastics — Preparation of test specimens by machining*

[A1⟩ ISO 3167:2002, *Plastics — Multipurpose test specimens* ⟨A1]

ISO 5893:1993, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Description*

ISO 10724-1:1998, *Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs) — Part 1: General principles and moulding of multipurpose test specimens*

3 Terms and definitions

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

3.1
test speed
v
rate of relative movement between the supports and the loading edge

NOTE It is expressed in millimetres per minute (mm/min).

3.2
flexural stress
σ_f
nominal stress of the outer surface of the test specimen at midspan

NOTE It is calculated from the relationship given in 9.1, equation (5), and is expressed in megapascals (MPa).

3.3
flexural stress at break
σ_{fB}
flexural stress at break of the test specimen (see Figure 1, curves a and b)

NOTE It is expressed in megapascals (MPa).

3.4
flexural strength
σ_{fM}
maximum flexural stress sustained by the test specimen during a bending test (see Figure 1, curves a and b)

NOTE It is expressed in megapascals (MPa).

1) To be published. (Revision of ISO 295:1991)

3.5
flexural stress at conventional deflection

σ_{fc}

flexural stress at the conventional deflection s_C defined in 3.7 (see Figure 1, curve c)

NOTE It is expressed in megapascals (MPa).

3.6
deflection

s

distance over which the top or bottom surface of the test specimen at midspan deviates from its original position during flexure

NOTE It is expressed in millimetres (mm).

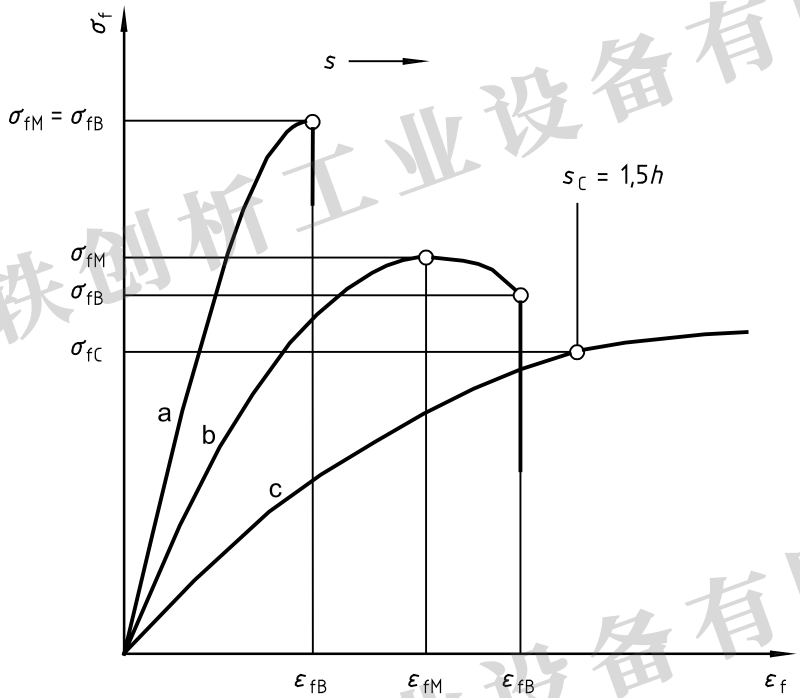
3.7
conventional deflection

s_C

deflection equal to 1,5 times the thickness h of the test specimen

NOTE 1 It is expressed in millimetres (mm).

NOTE 2 Using a span L of $16h$, the conventional deflection corresponds to a flexural strain (see 3.8) of 3,5 %.



Curve a Specimen that breaks before yielding.

Curve b Specimen that gives a maximum and then breaks before the conventional deflection s_C.

Curve c Specimen that neither gives a maximum nor breaks before the conventional deflection s_C.

Figure 1 — Typical curves of flexural stress σ_f versus flexural strain ε_f and deflection s

3.8
flexural strain
ε_f
nominal fractional change in length of an element of the outer surface of the test specimen at midspan

NOTE 1 It is expressed as a dimensionless ratio or as a percentage (%).

NOTE 2 It is calculated in accordance with the relationships given in 9.2, equations (6) and (7).

3.9
flexural strain at break
ε_{fB}
flexural strain at break of the test specimen (see Figure 1, curves a and b)

NOTE It is expressed as a dimensionless ratio or as a percentage (%).

3.10
flexural strain at flexural strength
ε_{fM}
flexural strain at maximum flexural stress (see Figure 1, curves a and b)

NOTE It is expressed as a dimensionless ratio or as a percentage (%).

3.11
modulus of elasticity in flexure
flexural modulus
E_f
ratio of the stress difference $\sigma_{f2} - \sigma_{f1}$ to the corresponding strain difference ε_{f2} (= 0,002 5) – ε_{f1} (= 0,000 5) [see 9.2, equation (9)]

NOTE 1 It is expressed in megapascals (MPa).

NOTE 2 The flexural modulus is only an approximate value of Young's modulus of elasticity.

NOTE 3 With computer-aided equipment, the determination of the modulus E_f using two distinct stress/strain points can be replaced by a linear regression procedure applied to the part of the curve between these two points.

3.12
rigid plastic
a plastic that has a modulus of elasticity in flexure or, if that is not applicable, then in tension, greater than 700 MPa under stated conditions [ISO 472]

4 Principle

The test specimen, supported as a beam, is deflected at a constant rate at the midspan until the specimen fractures or until the deformation reaches some predetermined value. During this procedure, the force applied to the test specimen is measured.

5 Test machine

5.1 General

The machine shall comply with ISO 5893 and the requirements given in 5.2 to 5.4.

5.2 Test speed

The machine shall be capable of maintaining the test speed (see 3.1), as specified in Table 1.

Table 1 — Recommended values of the test speed, v

Test speed, v mm/min	Tolerance %
1[a]	± 20[b]
2	± 20[b]
5	± 20
10	± 20
20	± 10
50	± 10
100	± 10
200	± 10
500	± 10

[a] The lowest speed is used for specimens with thicknesses between 1 mm and 3,5 mm (see 8.5).

[b] The tolerances on the 1 mm/min and 2 mm/min speeds are lower than indicated in ISO 5893.

Acceleration, seating and machine compliance may contribute to a curved region at the start of the stress/strain curve. This can be avoided as explained in 8.4 and 9.2.

5.3 Supports and loading edge

Two supports and a central loading edge shall be arranged as shown in Figure 2. The supports and the loading edge shall be parallel to within ± 0,2 mm over the width of the test specimen.

The radius R_1 of the loading edge and the radius R_2 of the supports shall be as follows:

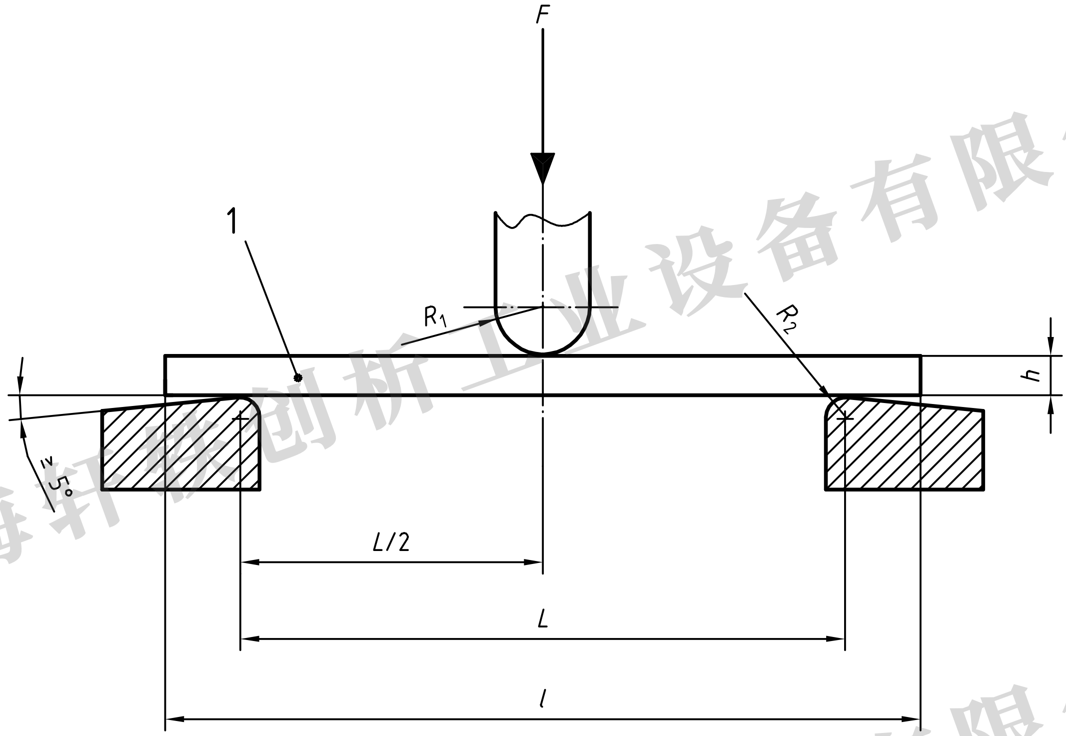
R_1 = 5,0 mm ± 0,1 mm;

R_2 = 2,0 mm ± 0,2 mm for test specimen thicknesses $\leqslant$ 3 mm;

R_2 = 5,0 mm ± 0,2 mm for test specimen thicknesses $>$ 3 mm.

The span L shall be adjustable.

NOTE It may be necessary to prestress the specimen to obtain correct alignment and specimen seating and to avoid a curved region at the start of the stress/strain curve (see 8.4).



Key

1 Test specimen

F Applied force

R_1 Radius of loading edge

R_2 Radius of supports

h Thickness of specimen

l Length of specimen

L Length of span between supports

Figure 2 — Position of test specimen at start of test

5.4 Load- and deflection-indicating equipment

The error in the indicated force shall not exceed 1 % of the actual value and the error in the indicated deflection shall not exceed 1 % of the actual value (see ISO 5893).

NOTE 1 When determining the flexural modulus, the actual values used are those corresponding to the upper limit of the strain difference, i.e. $\varepsilon_2 = 0{,}002\,5$. Thus when using the preferred specimen type (see 6.1.2), a specimen thickness *h* of 4 mm and a span *L* of 16*h* (see 8.3), for instance, equation (6) gives a deflection s_2 of 0,43 mm. In this case, the tolerance on the deflection-measuring system has to be ± 4,3 µm.

NOTE 2 Systems have become commercially available that use ring-shaped strain gauges, and thus any lateral forces which may be generated by misalignment of the test set-up are compensated for.

6 Test specimens

6.1 Shape and dimensions

6.1.1 General

The dimensions of the test specimens shall comply with the relevant material standard and, as applicable, with 6.1.2 or 6.1.3. Otherwise, the type of specimen shall be agreed between the interested parties.

6.1.2 Preferred specimen type

The dimensions, in millimetres, of the preferred test specimen are

length, l: 80 ± 2

width, b: 10,0 ± 0,2

thickness, h: 4,0 ± 0,2

In any one test specimen, the thickness within the central third of the length shall not deviate by more than 2 % from its mean value. The width shall not deviate from its mean value within this part of the specimen by more than 3 %. The specimen cross-section shall be rectangular, with no rounded edges.

NOTE The preferred specimen may be machined from the central part of a multipurpose test specimen complying with ISO 3167.

6.1.3 Other test specimens

When it is not possible or desirable to use the preferred test specimen, the following limits shall apply.

The length and thickness of the test specimen shall be in the same ratio as for the preferred test specimen, i.e.

$$\frac{l}{h} = 20 \pm 1 \qquad (1)$$

unless affected by the provisions of 8.3 a), 8.3 b) or 8.3 c).

NOTE Certain specifications require that test specimens from sheets of thickness greater than a specified upper limit shall be reduced to a standard thickness by machining one face only. In such cases, it is conventional practice to place the test specimen such that the original surface of the specimen is in contact with the two supports and the force is applied by the central loading edge to the machined surface of the specimen.

The width of the specimen shall be as given in Table 2.

Table 2 — Values of specimen width b in relation to thickness h

Dimensions in millimetres

Nominal thickness h	Width b[a]
$1 < h \leqslant 3$	25,0 ± 0,5
$3 < h \leqslant 5$	10,0 ± 0,5
$5 < h \leqslant 10$	15,0 ± 0,5
$10 < h \leqslant 20$	20,0 ± 0,5
$20 < h \leqslant 35$	35,0 ± 0,5
$35 < h \leqslant 50$	50,0 ± 0,5

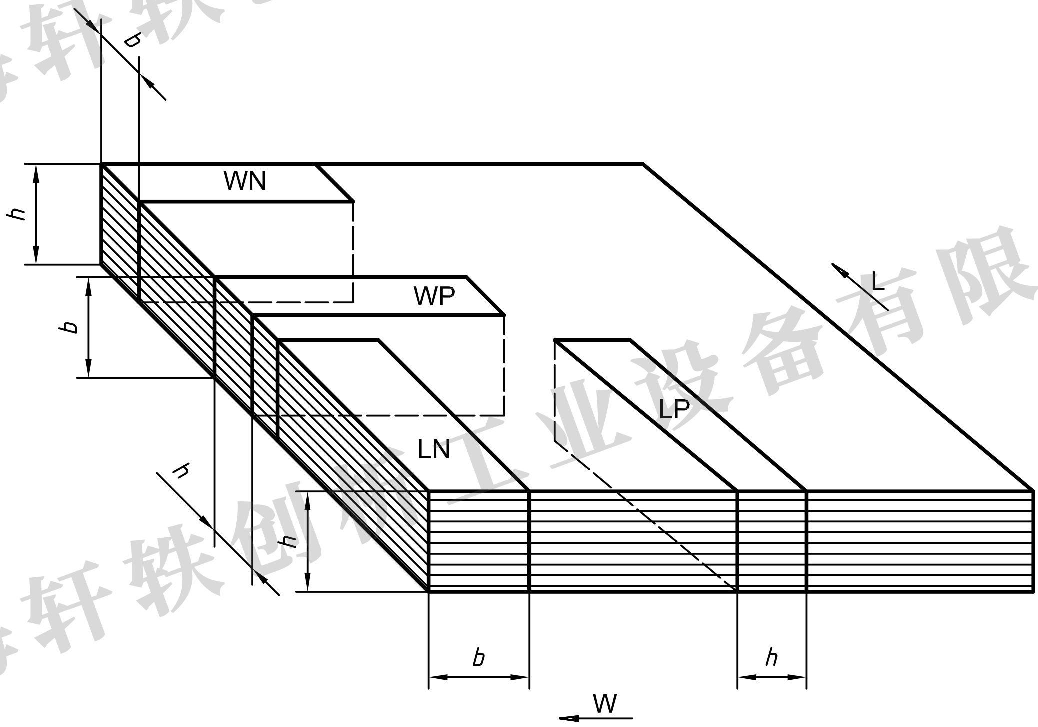
[a] For materials with very coarse fillers, the minimum width shall be 30 mm.

6.2 Anisotropic materials

6.2.1 In the case of materials having physical properties that depend on direction, e.g. elasticity, the test specimens shall be chosen so that the flexural stress will be applied in the same, or in a similar, direction as that to which products (moulded articles, sheets, tubes, etc.) will be subjected in service, if this direction is known. The relationship between the test specimen and the end-product envisaged will determine the feasibility of using standard test specimens.

NOTE The position or orientation and the dimensions of the test specimens sometimes have a very significant influence on the test results.

6.2.2 When the material shows a significant difference in flexural properties in two principal directions, it shall be tested in these two directions. The orientation of the test specimen relative to the principal directions shall be recorded (see Figure 3).



Key

L Product length direction

W Product width direction

Position of specimen	Product direction	Direction of force
LN	Length	Normal
WN	Width	
LP	Length	Parallel
WP	Width	

Figure 3 — Position of test specimen in relation to product direction and direction of force

6.3 Preparation of test specimens

6.3.1 Moulding and extrusion compounds

Specimens shall be prepared in accordance with the relevant material specification. When none exists, and unless otherwise specified, specimens shall be directly compression moulded or injection moulded from the material in accordance with ISO 293, ISO 294-1, ISO 295 or ISO 10724-1, as appropriate.

6.3.2 Sheets

Specimens shall be machined from sheets in accordance with ISO 2818.

6.4 Specimen inspection

The specimens shall be free of twist, and their opposite surfaces shall be parallel and adjacent surfaces perpendicular. All surfaces and edges shall be free from scratches, pits, sink marks and flash.

The specimens shall be checked for conformity with these requirements by visual observation against straight edges, squares and flat plates, and by measuring with micrometer calipers.

Specimens showing measurable or observable departures from one or more of these requirements shall be rejected or machined to proper size and shape before testing.

NOTE Injection-moulded test specimens usually have draft angles of between 1° and 2° to facilitate demoulding. Therefore, the side faces of moulded test specimens will generally not be quite parallel.

6.5 Number of test specimens

6.5.1 At least five test specimens shall be tested in each direction of test (see Figure 3). The number of specimens 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).

6.5.2 In the case of directly injection-moulded test specimens, at least five shall be tested.

NOTE It is recommended that specimens always be tested oriented in the same way, i.e. with the surface which was in contact with the cavity plate or that which was in contact with the fixed plate (see ISO 294-1 or ISO 10724-1, as appropriate) always in contact with the supports, in order to exclude the effects of any asymmetry generated by the moulding process.

6.5.3 The results from test specimens that rupture outside the central third of their span length shall be discarded and new test specimens tested in their place.

7 Conditioning

The test specimens shall be conditioned as specified in the standard for the material being tested. In the absence of this information, select the most appropriate conditions from ISO 291, unless otherwise agreed upon by the interested parties, e.g. for testing at high or low temperatures. The preferred set of conditions in ISO 291 is atmosphere 23/50, except when the flexural properties of the material are known to be insensitive to moisture, in which case humidity control is unnecessary.

8 Procedure

8.1 Conduct the test in the atmosphere specified in the standard for the material being tested. In the absence of this information, select the most appropriate conditions from ISO 291, unless otherwise agreed upon by the interested parties, e.g. for testing at high or low temperatures.

8.2 Measure the width b of the test specimens to the nearest 0,1 mm and the thickness h to the nearest 0,01 mm in the centre of the test specimens. Calculate the mean thickness $\bar{h}$ for the set of specimens.

Discard any specimens with a thickness exceeding the tolerance of ± 2 % of the mean value and replace them by other specimens chosen at random.

NOTE For the purposes of this International Standard, the test specimen dimensions used to calculate flexural properties are measured at room temperature only. For the measurement of properties at other temperatures, therefore, the effects of thermal expansion are not taken into account.

8.3 Adjust the span L to comply with the following equation:

$$L = (16 \pm 1)\,\bar{h} \qquad (2)$$

and measure the resulting span to the nearest 0,5 %.

Equation (2) shall be used except in the following cases:

a) For very thick and unidirectional fibre-reinforced test specimens, if necessary to avoid delamination in shear, use a span length based on a higher value of the ratio $L/\bar{h}$.

b) For very thin test specimens, if necessary to enable measurements to be made within the working range of the test machine, use a span length based on a lower value of the ratio $L/\bar{h}$.

c) For soft thermoplastics, if necessary to prevent indentation of the supports into the test specimen, use a higher value of the ratio $L/\bar{h}$.

8.4 Do not load the specimen substantially prior to testing. Such loads may be necessary, however, to avoid a curved region at the start of the stress/strain diagram. For modulus measurement, the flexural stress in the specimen at the start of a test σ_{f0} (see Figure 4) shall be positive and shall lie within the range

$$0 \leqslant \sigma_{f0} \leqslant 5 \times 10^{-4} E_f \qquad (3)$$

which corresponds to a prestrain of $\varepsilon_{f0} \leqslant 0{,}05$ %, and when measuring characteristics such as σ_{fM}, σ_{fC} or σ_{fB} it shall lie within the range

$$0 \leqslant \sigma_{f0} \leqslant 10^{-2} \sigma_f \qquad (4)$$

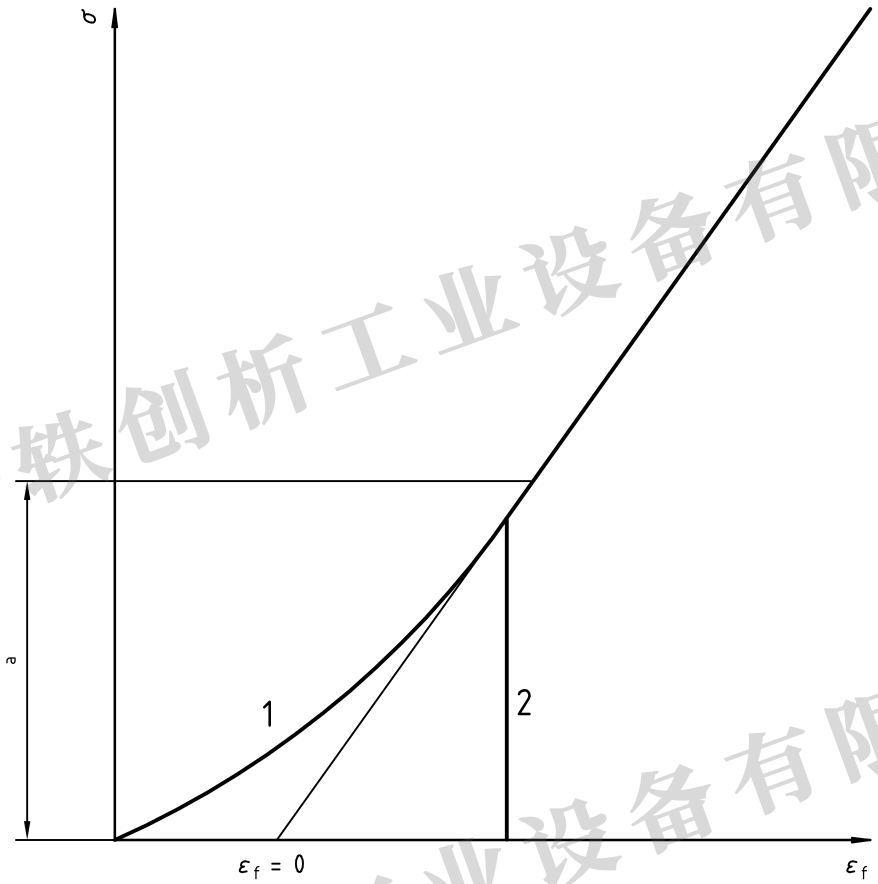
NOTE The flexural modulus of strongly viscoelastic, ductile materials like polyethylene, polypropylene or moist polyamides is influenced markedly by prestressing.

8.5 Set the test speed in accordance with the standard for the material being tested. In the absence of this information, select a value from Table 1 that gives a flexural strain rate as near as possible to 1 % per minute. This gives a test speed of 2 mm/min for the preferred test specimen specified in 6.1.2.

8.6 Place the test specimen symmetrically on the two supports and apply the force at midspan (see Figure 2).

8.7 Record the force and the corresponding deflection of the specimen during the test, using, if practicable, an automatic recording system that yields a complete flexural-stress/deflection curve for this operation [see 9.1, equation (5)].

Determine all relevant stresses, deflections and strains defined in clause 3 from a force/deflection or stress/deflection curve or from equivalent data. See annex A for a method of compliance correction.



Key

1 Initial part of stress/strain plot showing a curved region.

2 Initial part of stress/strain plot showing a step due to forces being measured only above a trigger threshold.

a $\leqslant 5 \times 10^{-4} E_f$ or $\leqslant 10^{-2} \sigma_f$

Figure 4 — Example of stress/strain plots with an initial curved region and with a step, and determination of zero-strain point

9 Calculation and expression of results

9.1 Flexural stress

Calculate the flexural-stress parameters defined in clause 3 using the following equation:

$$\sigma_f = \frac{3FL}{2bh^2} \quad (5)$$

where

σ_f is the flexural-stress parameter in question;

F is the applied force, in newtons;

L is the span, in millimetres;

b is the width, in millimetres, of the specimen;

h is the thickness, in millimetres, of the specimen.

9.2 Flexural strain

Calculate the flexural-strain parameters defined in clause 3 using one of the following equations:

$$\varepsilon_f = \frac{6sh}{L^2} \quad (6)$$

$$\varepsilon_f = \frac{600sh}{L^2}\ \% \quad (7)$$

where

ε_f is the flexural-strain parameter in question, expressed as a dimensionless ratio or as a percentage;

s is the deflection, in millimetres;

h is the thickness, in millimetres, of the test specimen;

L is the span, in millimetres.

If a curved region is found in the initial part of the stress/strain diagram, extrapolate to zero strain from stresses slightly above the initial flexural stress described in 8.4 (see also Figure 4).

9.3 Flexural modulus

To determine the flexural modulus, calculate the deflections s_1 and s_2 corresponding to the given values of the flexural strain $\varepsilon_{f1} = 0{,}000\,5$ and $\varepsilon_{f2} = 0{,}002\,5$ using the following equation:

$$s_i = \frac{\varepsilon_{fi} L^2}{6h} \qquad (i = 1;\ 2) \quad (8)$$

where

s_i is one of the deflections, in millimetres;

ε_{fi} is the corresponding flexural strain, whose values ε_{f1} and ε_{f2} are given above;

L is the span, in millimetres;

h is the thickness, in millimetres, of the specimen.

Calculate the flexural modulus E_f, expressed in megapascals, using the following equation:

$$E_f = \frac{\sigma_{f2} - \sigma_{f1}}{\varepsilon_{f2} - \varepsilon_{f1}} \quad (9)$$

where

σ_{f1} is the flexural stress, in megapascals, measured at deflection s_1;

σ_{f2} is the flexural stress, in megapascals, measured at deflection s_2.

For computer-aided equipment, see note 3 to 3.11.

NOTE All equations concerning flexural properties hold exactly for linear stress/strain behaviour only (see 1.6); thus for most plastics they are accurate at small deflections only. The equations given may, however, be used for comparison purposes.

9.4 Statistical parameters

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

9.5 Significant figures

Calculate the stresses and the modulus to three significant figures. Calculate the deflections to two significant figures.

10 Precision

[A1) For precision data, see Annex B. (A1]

11 Test report

The test report shall include the following information:

a) a reference to this International Standard;

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

c) for sheets, the thickness of the sheet and, if applicable, the directions of the major axes of the specimens in relation to some feature of the sheet;

d) the shape and dimensions of the test specimens;

e) the method of preparing the specimens;

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

g) the number of specimens tested;

h) the nominal span used;

i) the test speed;

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

k) the surface on which the force was applied;

l) the individual test results, if required;

m) the mean values of the individual results;

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

o) the date of the test.

Annex A
(normative)

Compliance correction

If the deflection s cannot be measured directly and must be replaced by precisely recording the change s_C in the distance between the crossheads of the test machine, this change in distance shall be corrected for the compliance C_M of the machine. C_M is determined using a reference bar of highly rigid reference material of known tensile modulus, e.g. steel sheeting. The deflection s is calculated using the equations

$$s = s_C - C_M F \quad \text{(A.1)}$$

and

$$C_M = \frac{s_R}{F} - \frac{L_R^3}{4 E_R b_R h_R^3} \quad \text{(A.2)}$$

where

- s is the deflection, in millimetres;
- s_C is the change, in millimetres, in the distance between two selected points on the test machine;
- C_M is the compliance, in millimetres per newton, of the test machine between the selected points;
- s_R is the change, in millimetres, in the distance between the selected points when using the reference specimen;
- F is the force, in newtons;
- E_R is the tensile modulus, in megapascals, of the reference material;
- L_R is the span, in millimetres, during compliance determination;
- b_R is the width, in millimetres, of the reference specimen;
- d_R is the thickness, in millimetres, of the reference specimen.

Alternatively, if it is possible to measure precisely the deflection Δs_R of the reference specimen relative to the supports, the machine compliance can be determined from the equation

$$C_M = \frac{1}{F}\left(s^* - \Delta s_R\right) \quad \text{(A.3)}$$

where

- s^* is the displacement indicated by the equipment during the test, e.g. crosshead displacement;
- Δs_R is the deflection of the reference specimen as determined by a calibrated reference instrument.

In this case, the modulus of the reference material does not have to be known.

Ensure that the compliance C_M is constant for the relevant range of forces. The simple linear relation assumed here ($s_C = C_M \times F$) for machine deformation due to compliance may be not valid if e.g. seating effects in one or more components of the machine occur.

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Annex B
(informative)

Precision statement

B.1 Tables B.1 and B.2 are based on a round-robin test performed in accordance with ASTM E 691, *Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method*. All materials were sampled and distributed by one source. Each "test result" was the average of five individual determinations. Each laboratory obtained and reported two test results for each material.

B.2 Table B.1 is based on a round robin involving nine laboratories and four materials and Table B.2 is based on a round-robin involving eleven laboratories and four materials.

NOTE The following explanations of r and R (see Clause B.3) are only intended to present a meaningful way of considering the *approximate* precision of this test method. The data in Tables B.1 and B.2 should not be rigorously applied to acceptance or rejection of material, as those data are specific to the round robin and may not be representative of other lots, conditions, materials or laboratories. Users of this test method should apply the principles of ASTM E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of Clause B.3 would then be valid for such data.

B.3 Concept of r and R in Tables B.1 and B.2: If s_r and s_R have been calculated from a large enough body of data, and for test results that were averages from testing five specimens for each test result, then:

a) **Repeatability:** Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the r-value for that material, r being the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment in the same laboratory.

b) **Reproducibility:** Two test results obtained by different laboratories shall be judged not equivalent if they differ by more than the R-value for that material, R being the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

c) The judgments in a) and b) will have an approximately 95 % (0,95) probability of being correct.

Table B.1 — Precision data for flexural stress at a conventional deflection of 3,5 % [a]

Values in megapascals

Material	Average	s_r	s_R	r	R
Polycarbonate	70,5	0,752	1,99	2,11	5,58
ABS	72,1	0,382	2,67	1,07	7,49
HDPE	20,4	0,129	0,505	0,36	1,42
GF polysulfone	156 [a]	1,65	3,13	4,62	8,75

NOTE For the meanings of the algebraic symbols used, see Table B.2.

[a] For GF polysulfone, the flexural strength was measured.

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Table B.2 — Precision data for flexural modulus

Values in megapascals

Material	Average	s_r	s_R	r	R
Polycarbonate	2 310	45,6	146	128	410
ABS	2 470	33,6	157	94,0	439
HDPE	1 110	15,0	94,4	41,9	264
GF polysulfone	8 510	83,5	578	234	1 618

s_r = within-laboratory standard deviation

s_R = between-laboratory standard deviation

r = 95 % repeatability limit (= 2,8s_r)

R = 95 % reproducibility limit (= 2,8s_R)

A1

Bibliography

[1] ISO 527-1:1993, *Plastics — Determination of tensile properties — Part 1: General principles*

[2] ISO 14125:1998, *Fibre-reinforced plastic composites — Determination of flexural properties*

[3] ISO 1209-1:1990, *Cellular plastics, rigid — Flexural tests — Part 1: Bending test*

[4] ISO 1209-2:1990, *Cellular plastics, rigid — Flexural tests — Part 2: Determination of flexural properties*

[5] ISO 472:1999, *Plastics — Vocabulary*

Annex ZA
(normative)

Normative references to international publications with their relevant European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE Where an International Publication has been modified by common modifications, indicated by (mod.), the relevant EN/HD applies.

Publication	Year	Title	EN	Year
ISO 291	1997	Plastics - Standard atmospheres for conditioning and testing	EN ISO 291	1997
ISO 294-1	1996	Plastics - Injection moulding of test specimens of thermoplastic materials - Part 1: General principles, and moulding of multipurpose and bar test specimens	EN ISO 294-1	1998
ISO 295	1991	Plastics - Compression moulding of test specimens of thermosetting materials	EN ISO 295	1998
ISO 2818	1994	Plastics - Preparation of test specimens by machining	EN ISO 2818	1996
ISO 3167	1993	Plastics - Multipurpose-test specimens	EN ISO 3167	1996
ISO 10724-1	1998	Plastics - Injection moulding of test specimens o f thermosetting powder moulding compounds (PMCs) - Part 1: General principles and moulding of multi purpose test specimens	EN ISO 10724-1	2001

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