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Plastics — Determination of flexural properties

Plastiques — Détermination des propriétés en flexion

Reference number
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Contents

Page

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*

ISO 3167:2001, *Plastics — Multipurpose test specimens*

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).

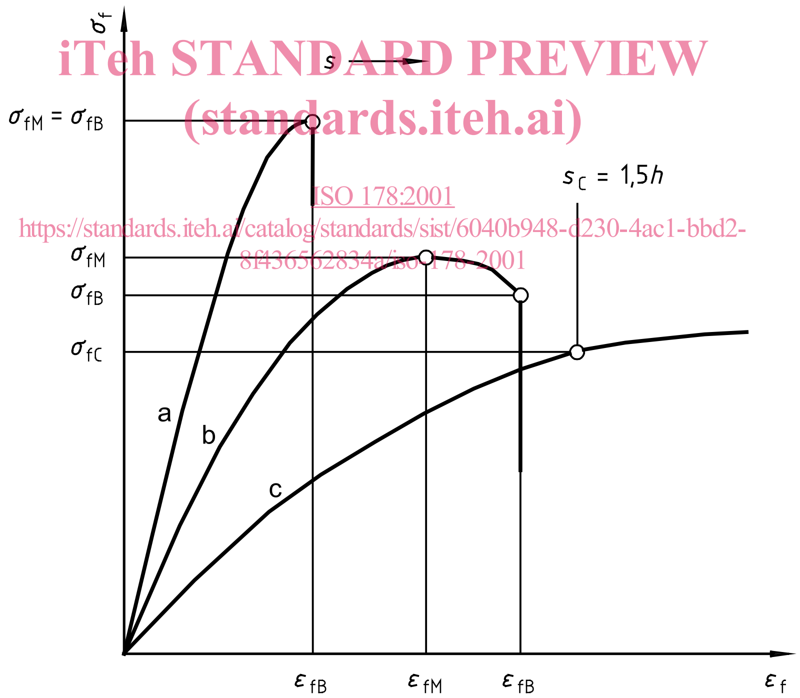
3.7
conventional deflection

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:

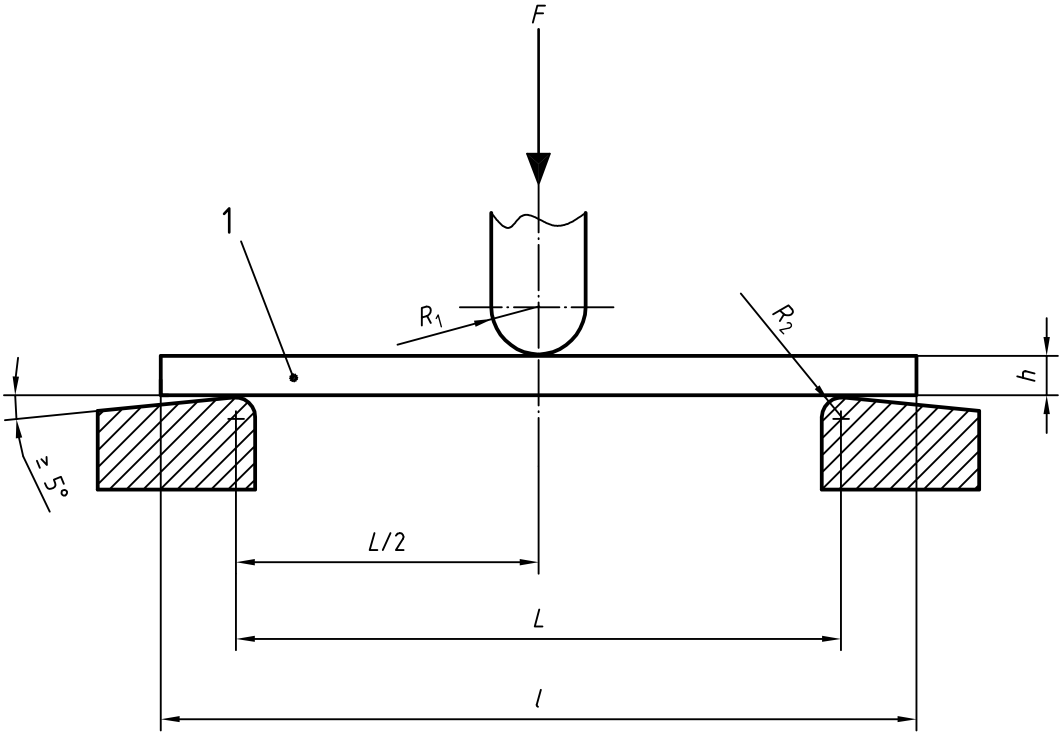
R_1 = 5,0 mm ± 0,1 mm;

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	h	Thickness of specimen
F	Applied force	l	Length of specimen
R_1	Radius of loading edge	L	Length of span between supports
R_2	Radius of 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 16h (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.