INTERNATIONAL STANDARD

ISO 178

Fifth edition
2010-12-15

Plastics — Determination of flexural properties

Plastiques — Détermination des propriétés en flexion

Reference number
ISO 178:2010(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

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

This fifth edition cancels and replaces the fourth edition (ISO 178:2001), which has been technically revised to harmonize it with ISO 527-2[2] with respect to the test speeds used for the determination of the flexural modulus and for the determination of other flexural properties. This has been done by specifying two methods, method A and method B. Method A is identical to the method specified in previous editions of ISO 178, i.e. it uses the same strain rate throughout the test, whereas method B uses two different strain rates (see 1.8 for details).

It also incorporates the Amendment ISO 178:2001/Amd.1:2004.

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 of the test specimens and to determine 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:

— thermoplastic moulding, extrusion and casting 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[5] and ISO 10350-2[6], 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 ISO 14125[7].

The method is not normally suitable for use with rigid cellular materials or sandwich structures containing cellular material. In such cases, ISO 1209-1[3] and/or ISO 1209-2[4] can be used.

NOTE For certain types of textile-fibre-reinforced plastic, a four-point bending test is preferred. This is described in ISO 14125.

1.4 The method is performed using specimens which may be either moulded to the specified dimensions, machined from the central section of a standard multipurpose test specimen (see ISO 20753) or machined from finished or semi-finished products, such as mouldings, laminates, or extruded or cast sheet.

1.5 The method specifies the 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, can produce results which are not comparable. Other factors, such as the test speed and the conditioning of the specimens, can also influence the results.

NOTE Especially for semi-crystalline polymers, the thickness of the oriented skin layer, which is dependent on the moulding conditions, also affects the flexural properties.

1.6 The method is not suitable for the determination of design parameters but can be used in materials testing and as a quality control test.

1.7 For materials exhibiting non-linear stress/strain behaviour, the flexural properties are only nominal. The equations given have been derived assuming linear elastic behaviour and are valid for deflections of the specimen that are small compared to its thickness. With the preferred specimen (which measures 80 mm × 10 mm × 4 mm) at the conventional flexural strain of 3,5 % and a span-to-thickness ratio, L/h, of 16, the deflection is 1,5h. Flexural tests are more appropriate for stiff and brittle materials showing small deflections at break than for very soft and ductile ones.

1.8 Contrary to the previous editions of this International Standard, this edition specifies two methods, method A and method B. Method A is identical to the method in previous editions of this International Standard, i.e. it uses a strain rate of 1 %/min throughout the test. Method B uses two different strain rates: 1 %/min for the determination of the flexural modulus and 5 %/min or 50 %/min, depending on the ductility of the material, for the determination of the remainder of the flexural stress-strain curve.

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 293, *Plastics — Compression moulding of 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 test specimens*

ISO 295, *Plastics — Compression moulding of test specimens of thermosetting materials*

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

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

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

ISO 9513, *Metallic materials — Calibration of extensometers used in uniaxial testing*

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

ISO 16012, *Plastics — Determination of linear dimensions of test specimens*

ISO 20753, *Plastics — Test specimens*

ISO 23529, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*

3 Terms and definitions

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

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

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

3.2
flexural stress
σ_f
nominal stress at 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).

3.5
flexural stress at conventional deflection
σ_{fc}
flexural stress at the conventional deflection, s_C, defined in 3.7 (see also 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

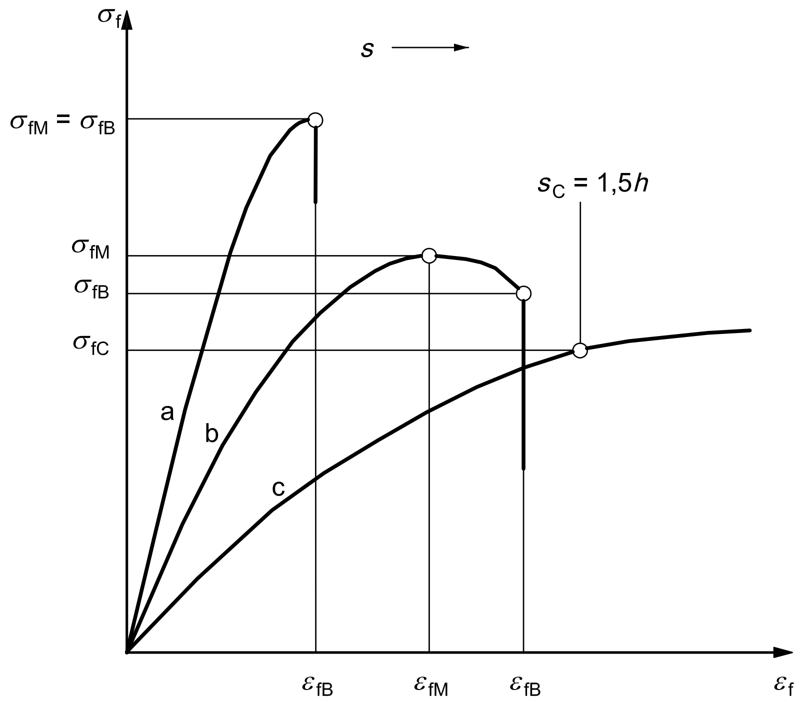
NOTE 1 It is expressed in millimetres (mm).

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

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 a percentage (%).

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



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

3.9
flexural strain at break

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

NOTE	It is expressed as a dimensionless ratio or 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 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 9.3, 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.

3.12
rigid plastic
plastic that has a modulus of elasticity in flexure or, if that is not applicable, then in tension, greater than 700 MPa

[ISO 472[1]]

3.13
span between specimen supports
L
distance between the points of contact between the test specimen and the test specimen supports (see Figure 2)

NOTE It is expressed in millimetres (mm).

3.14
flexural strain rate
r
rate at which the flexural strain (see 3.8) increases during a test

NOTE It is expressed in reciprocal seconds (s^{-1}) or percent per second ($\%\cdot s^{-1}$).

4 Principle

A test specimen of rectangular cross-section, resting on two supports, is deflected by means of a loading edge acting on the specimen midway between the supports. The test specimen is deflected in this way at a constant rate at midspan until rupture occurs at the outer surface of the specimen or until a maximum strain of 5 % (see 3.8) is reached, whichever occurs first. During this procedure, the force applied to the specimen and the resulting deflection of the specimen at midspan are measured.

5 Test machine

5.1 General

The machine shall comply with ISO 7500-1 and ISO 9513 and the requirements given in 5.2 to 5.4.

5.2 Test speed

The test 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
2	±20
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 also 8.5).

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.

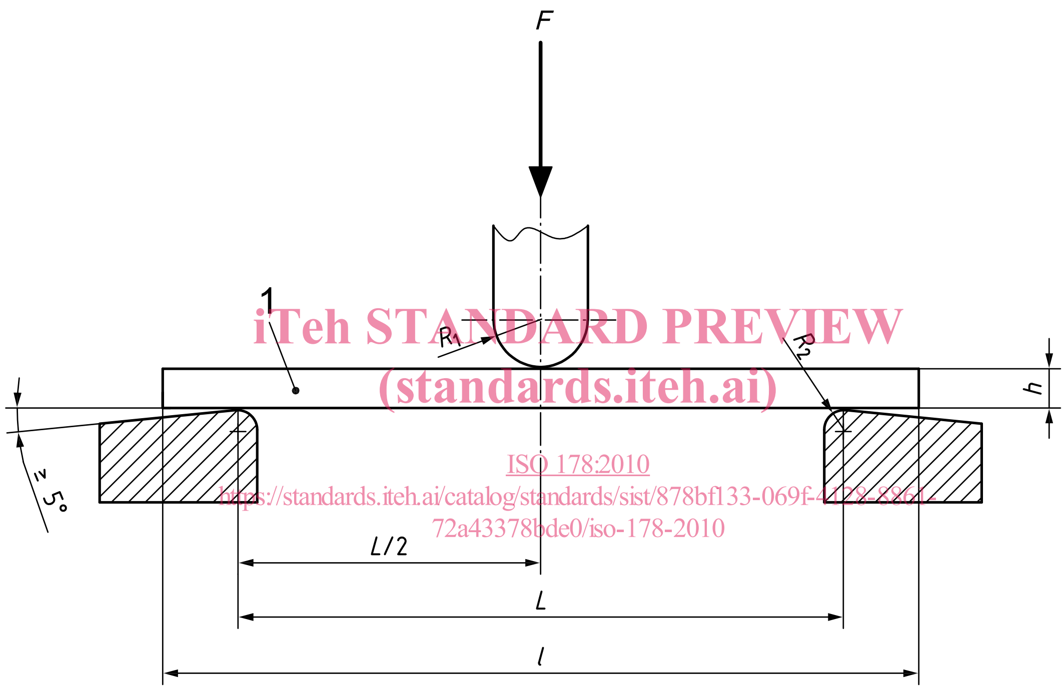
The radius, R_1, of the loading edge and the radius, R_2, of the supports shall be as follows:

R_1 = 5,0 mm ± 0,2 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.



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 Force- and deflection-measuring systems

5.4.1 Force-measuring system

The force-measuring system shall comply with the requirements of class 1 as defined in ISO 7500-1.

5.4.2 Deflection-measuring system

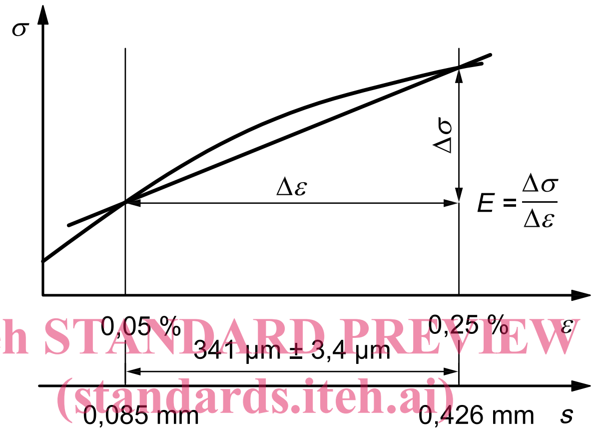
The deflection-measuring system shall comply with the requirements of class 1 as defined in ISO 9513. This shall be valid over the whole range of deflections to be measured. Non-contact systems may be used provided they meet the accuracy requirements stated above. The measurement system shall not be influenced by machine compliance.

When determining the flexural modulus, the deflection-measuring system shall be capable of measuring the change in deflection to an accuracy of 1 % of the relevant value or better, corresponding to ±3,4 µm for a support span, L, of 64 mm and a specimen thickness, h, of 4,0 mm (see Figure 3). Other support spans and specimen thicknesses will lead to different requirements for the accuracy of the deflection-measuring system.

Any deflection indicator capable of measuring deflection to the accuracy specified above is suitable.

NOTE The crosshead displacement includes not only the specimen deflection but also the indentation of the loading edge and the supports into the specimen and deformation of the machine. The last of these is machine-dependent as well as load-dependent. Results determined on different types of machine are therefore not comparable.

In general, measurement of crosshead displacement is not suitable for modulus determination unless a compliance correction is applied.



Key

σ flexural stress

ε flexural strain

s corresponding deflection for a specimen thickness of 4 mm and a span between supports of 64 mm

Figure 3 — Accuracy requirements for determination of flexural modulus

5.5 Equipment for measuring the width and thickness of the test specimens

5.5.1 Rigid materials

5.5.1.1 Specimen thickness

Measure the thickness using a micrometer, at points lying within ±2 mm of the centre of the specimen, in accordance with ISO 16012, but using a micrometer that has an accuracy of ±0,01 mm as opposed to the accuracy of ±0,02 mm specified in ISO 16012. The presser foot shall have a flat, circular contact face with a diameter of $\geqslant$ 4 mm and the anvil shall have a spherical contact face of radius 50 mm to avoid errors caused by misalignment with the test piece.

5.5.1.2 Specimen width

Measure the width in accordance with ISO 16012, using a micrometer that has an accuracy of ±0,02 mm as specified in ISO 16012. The presser foot shall have either a flat contact face which is circular with a diameter of 1 mm or a rectangular contact face with the side which will be parallel to the specimen thickness direction 1 mm long.

