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Plastics — Determination of flexural properties

Plastiques — Détermination des propriétés en flexion

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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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.

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 voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties*.

This sixth edition cancels and replaces the fifth edition (ISO 178:2010), which has been technically revised. It also incorporates the Amendment ISO 178:2010/Amd.1:2013. The main changes compared to the previous edition are as follows:

— differentiating calibration requirements according to the type of test;

— the introduction of deflectometers;

— the reinstatement of procedures for compliance correction;

— the addition of a new Annex D showing the relation between tensile and flexural modulus.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Plastics — Determination of flexural properties

1 Scope

This document specifies a method for determining the flexural properties of rigid and semi-rigid plastics under defined conditions. A preferred test specimen is defined, but parameters are included for alternative specimen sizes for use where appropriate. A range of test speeds is included.

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).

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 document applies to fibre-reinforced compounds with fibre lengths ≤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 1 For certain types of textile-fibre-reinforced plastic, a four-point bending test is used. This is described in ISO 14125.

The method is performed using specimens which can 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.

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

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 294-1:2017, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 1: General principles, and moulding of multipurpose and bar test specimens*

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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 — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 9513, *Metallic materials — Calibration of extensometer systems 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*

3 Terms, definitions and symbols

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org

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

Note 1 to entry: 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 1 to entry: It is calculated from the relationship given in Formula (5).

Note 2 to entry: It is expressed in megapascals (MPa).

3.3
flexural stress at break
σ_{fB}
flexural stress at break of the test specimen

Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: See Figure 1, curves a and b.

3.4
flexural strength
σ_{fM}
maximum *flexural stress* (3.2) sustained by the test specimen during a bending test

Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: See Figure 1, curves a and b.

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3.5
flexural stress at conventional deflection
σ_{fc}
flexural stress at the *conventional deflection*, s_C (3.7)

Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: See also Figure 1, curve c.

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 1 to entry: It is expressed in millimetres (mm).

3.7
conventional deflection
s_C
deflection (3.6) equal to 1,5 times the thickness, h, of the test specimen

Note 1 to entry: It is expressed in millimetres (mm).

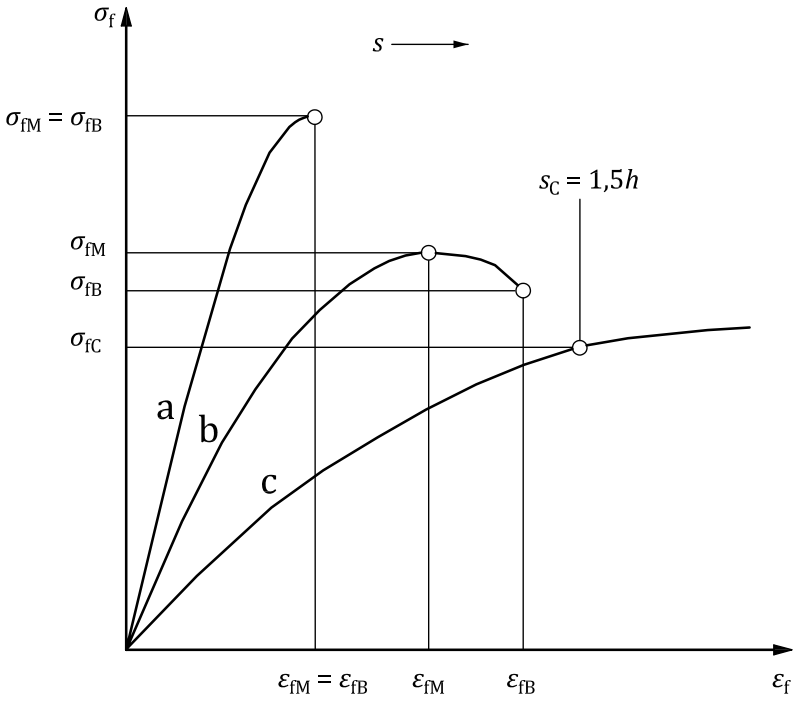
Note 2 to entry: Using a span, L, of $16h$, the conventional deflection corresponds to a *flexural strain* (3.8) of 3,5 %.

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 to entry: It is expressed as a dimensionless ratio or a percentage (%).

Note 2 to entry: It is calculated in accordance with the relationships given in Formulae (6) and (7).

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Key

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

Note 1 to entry: It is expressed as a dimensionless ratio or a percentage (%).

Note 2 to entry: See Figure 1, curves a and b.

3.10
flexural strain at flexural strength

ε_{fM}

flexural strain at maximum flexural stress

Note 1 to entry: It is expressed as a dimensionless ratio or a percentage (%).

Note 2 to entry: See Figure 1, curves a and b.

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)

Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: The flexural modulus is only an approximate value of Young's modulus.

Note 3 to entry: See Formula (9).

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3.12
rigid plastic
plastic that has a *modulus of elasticity in flexure* (3.11) or, if that is not applicable, then in tension, greater than 700 MPa under a given set of conditions

[SOURCE: ISO 472:2013, 2.884, modified — Note to entry has been omitted.]

3.13
semi rigid plastic
plastic that has a *modulus of elasticity in flexure* (3.11) or, if that is not applicable, then in tension, between 70 MPa and 700 MPa under a given set of conditions

[SOURCE: ISO 472:2013, 2.909, modified — Note to entry has been omitted.]

3.14
span between specimen supports
L
distance between the points of contact between the test specimen and the test specimen supports

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: See Figure 2.

3.15
flexural strain rate
r
rate at which the *flexural strain* (3.8) increases during a test

Note 1 to entry: It is expressed in percent per minute ($\% \cdot \text{min}^{-1}$).

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.

This document specifies two methods: method A and method B. Method A 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.

NOTE 1 The strain rates mentioned above are to be interpreted as nominal ones. Nominal test speeds are calculated using Formula (4). For the machine settings the best fitting ones are selected from Table 1.

NOTE 2 For materials exhibiting nonlinear stress/strain behaviour, the flexural properties are only nominal. The formulae 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.

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.

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