INTERNATIONAL STANDARD

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Plastics — Determination of compressive properties

Plastiques — Détermination des propriétés en compression

Reference number
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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.

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

ISO 604 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties*.

This third edition cancels and replaces the second edition (ISO 604:1993), which has been technically revised.

— a method of correcting for curvature at the beginning of the stress/strain curve is given (see 10.2.2);

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

Annexes A and C form a normative part of this International Standard. Annex B is for information only.

Plastics — Determination of compressive properties

1 Scope

This International Standard specifies a method for determining the compressive properties of plastics under defined conditions. A standard test specimen is defined but its length may be adjusted to prevent buckling under load from affecting the results. A range of test speeds is included.

The method is used to investigate the compressive behaviour of the test specimens and for determining the compressive strength, compressive modulus and other aspects of the compressive stress/strain relationship under the conditions defined.

The method applies to the following range of materials:

— rigid and semi-rigid [1] thermoplastic moulding and extrusion materials, including compounds filled and reinforced by e.g. short fibres, small rods, plates or granules in addition to unfilled types; rigid and semi-rigid thermoplastic sheet;

— rigid and semi-rigid thermoset moulding materials, including filled and reinforced compounds; rigid and semi-rigid thermoset sheet;

— thermotropic liquid-crystal polymers.

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.

The method is not normally suitable for use with materials reinforced by textile fibres (see references [2] and [5]), fibre-reinforced plastic composites and laminates (see [5]), rigid cellular materials (see [3]) or sandwich structures containing cellular material or rubber (see [4]).

The method is performed using specimens which may be moulded to the chosen 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.

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. Consequently, when comparable data are required, these factors must be carefully controlled and recorded.

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 test 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:—[2], *Plastics — Multipurpose test specimens*

ISO 5893:—[3], *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Specification*

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 (see also Figure 1).

3.1
gauge length
L_0
initial distance between the gauge marks on the central part of the test specimen

NOTE It is expressed in millimetres (mm).

3.2
test speed
v
rate of approach of the plates of the test machine during the test

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

3.3
compressive stress
σ
compressive load, per unit area of original cross-section, carried by the test specimen

NOTE 1 It is expressed in megapascals (MPa).

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

2) To be published. (Revision of ISO 3167:1993)

3) To be published. (Revision of ISO 5893:1993)

NOTE 2 In compression tests, the stresses σ and strains ε are negative. The negative sign, however, is generally omitted. If this generates confusion, e.g. in comparing tensile and compressive properties, the negative sign may be added for the latter. This is unnecessary for the nominal compressive strain ε_c.

3.3.1
compressive stress at yield
σ_y
first stress at which an increase in strain (see 3.4) occurs without an increase in stress (see Figure 1, curve a, and note 2 to 3.3)

NOTE 1 It is expressed in megapascals (MPa).

NOTE 2 It may be less than the maximum attainable stress.

3.3.2
compressive strength
σ_M
maximum compressive stress sustained by the test specimen during a compressive test (see Figure 1 and note 2 to 3.3)

NOTE It is expressed in megapascals (MPa).

3.3.3
compressive stress at break (rupture)
σ_B
compressive stress at break of the test specimen (see Figure 1 and note 2 to 3.3)

NOTE It is expressed in megapascals (MPa).

3.3.4
compressive stress at x % strain
σ_x
stress at which the strain reaches a specified value x % (see 3.5)

NOTE 1 It is expressed in megapascals (MPa).

NOTE 2 The compressive stress at x % strain may be measured, e.g., if the stress/strain curve does not exhibit a yield point (see Figure 1, curve b, and note 2 to 3.3). In this case, x is taken from the relevant product standard or agreed upon by the interested parties. In any case, x will have to be lower than the strain at compressive strength.

3.4
compressive strain
ε
decrease in length per unit original gauge length L_0 [see 10.2, equation (6), and note 2 to 3.3]

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

3.5
nominal compressive strain
ε_c
decrease in length per unit original length L of the test specimen [see 10.2, equation (8)]

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

3.5.1
nominal compressive yield strain
ε_{cy}
strain corresponding to the compressive stress at yield σ_y (see 3.3.1)

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

3.5.2
nominal compressive strain at compressive strength

ε_{cM}
strain corresponding to the compressive strength σ_M (see 3.3.2)

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

3.5.3
nominal compressive strain at break

ε_{cB}
strain at break of the test specimen

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

3.6
compressive modulus

E_c
ratio of the stress difference $(\sigma_2 - \sigma_1)$ to the corresponding strain difference values ($\varepsilon_2 = 0{,}002\,5$ minus $\varepsilon_1 = 0{,}000\,5$) [see 10.3, equation (9)]

NOTE 1 It is expressed in megapascals (MPa).

NOTE 2 The compression modulus is calculated on the basis of the compressive strain ε only (see 3.4).

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

4 Principle

The test specimen is compressed along its major axis at constant speed until the specimen fractures or until the load or the decrease in length reaches a predetermined value. The load sustained by the specimen is measured during this procedure.

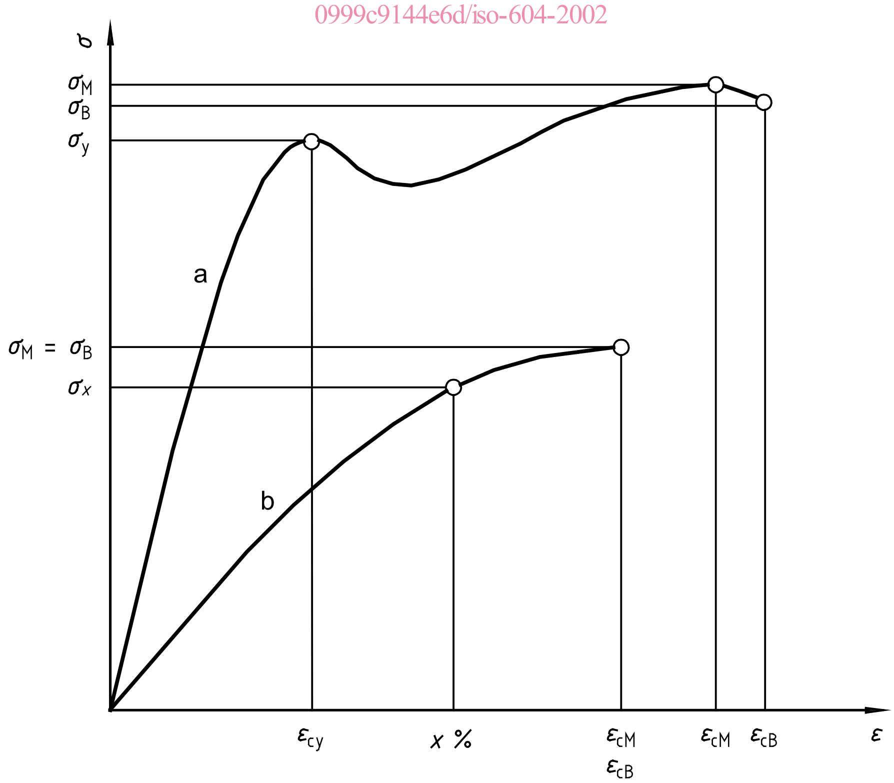

Figure 1 — Typical stress/strain curves

5 Apparatus

5.1 Test machine

5.1.1 General

The test machine shall comply with ISO 5893, and meet the specifications given in 5.1.2 to 5.1.5, as follows.

5.1.2 Test speeds

The machine shall be capable of maintaining the test speeds as specified in Table 1. If other speeds are used, the machine shall be capable of maintaining the speed to a tolerance of ± 20 % for speeds less than 20 mm/min and ± 10 % for speeds greater than 20 mm/min.

Table 1 — Recommended test speeds

Test speed v mm/min	Tolerance %
1	± 20
2	± 20
5	± 20
10	± 20
20	± 10 [a]

[a] This tolerance is smaller than that 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 9.4 and 9.6.

5.1.3 Compression tool

Hardened-steel compression plates shall be used to apply the deformation load to the test specimen, so constructed that the load sustained by the specimen is axial to within 1:1 000 and is transmitted through polished surfaces which are flat to within 0,025 mm, parallel to each other and perpendicular to the loading axis.

NOTE A self-aligning device may be used where required.

5.1.4 Load indicator

The load indicator shall incorporate a mechanism capable of showing the total compressive force sustained by the test specimen. The mechanism shall be essentially free of inertia lag at the specified test speed and shall indicate the value of the load with an accuracy of ± 1 %, or better, of the relevant value.

NOTE 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 (see 9.3).

5.1.5 Extensometer

The extensometer shall incorporate a mechanism suitable for determining the relative change in length of the appropriate part of the test specimen. If compressive strain ε is to be measured (the preferred approach), then this length is the gauge length; otherwise, for nominal compressive strain ε_c, it is the distance between the contact surfaces of the compression tool. It is desirable, but not essential, that this instrument automatically records this distance.

The instrument shall be essentially free of inertia lag at the specified test speed. For modulus determination using a type A specimen, it shall be accurate to ± 1 %, or better, of the strain interval used. This corresponds to ± 1 µm for the measurement of the compressive modulus, based on a gauge length of 50 mm and a strain interval of 0,2 %.

When the extensometer is attached to the test specimen, care shall be taken to ensure that any distortion of or damage to the test specimen is minimal. It is also essential that there is no slippage between the extensometer and the test specimen.

The specimens may also be instrumented with longitudinal strain gauges, the accuracy of which shall be 1 %, or better, of the strain interval used. This corresponds to a strain accuracy of $2{,}0 \times 10^{-5}$ for the measurement of the modulus. The gauges, the specimen surface preparation method and the bonding agents used shall be chosen to ensure adequate performance with the material under test.

NOTE Slight misalignment and initial warpage of the test specimen may generate differences in strain between the opposite surfaces of the specimen, resulting in errors at low strains. In these cases, the use of strain-measuring methods that average the strain on the two opposite sides of the specimen may be used. However, the use of strain gauges on either side of the specimen, with independent data collection, will detect buckling and bending much more rapidly than will devices that average the strain on the opposite surfaces.

5.2 Devices for measuring the dimensions of the test specimens

5.2.1 Rigid materials

Use a micrometer, or equivalent, reading to 0,01 mm or better, to measure the thickness, width and length.

The dimensions and shape of the anvils shall be suitable for the specimens being tested and shall not exert a force on the specimen such as to detectably alter the dimension being measured.

5.2.2 Semi-rigid materials

Micrometer, or equivalent, reading to 0,01 mm or better and provided with a flat circular foot which applies a pressure of 20 kPa ± 3 kPa, to measure the thickness.

6 Test specimens

6.1 Shape and dimensions

6.1.1 General

Test specimens shall be in the shape of a right prism, cylinder or tube.

The dimensions of the test specimens shall be such that the following inequality is satisfied (see also annex B):

$$\varepsilon_c^* \leqslant 0{,}4 \frac{x^2}{l^2} \tag{1}$$

where

ε_c^* is the maximum nominal compressive strain, expressed as a dimensionless ratio, which occurs during the test;

l is the length of the specimen, measured parallel to the axis of the compressive force;

x is the diameter of the cylinder, the outer diameter of the tube or the thickness (the shortest side of the cross-section) of the prism, depending on the shape of the test specimen.

NOTE 1 For measurement of the compressive modulus E_c as defined in 3.6, a value of the dimensionless ratio x/l of $> 0{,}08$ is recommended.

NOTE 2 When carrying out compression tests in general, a value of the dimensionless ratio x/l of $\geqslant 0{,}4$ is recommended. This corresponds to a maximum compressive strain of about 6 %.

Equation (1) is based upon the linear stress/strain behaviour of the material under test. Values of ε^*_c two to three times higher than the maximum strain used in the test shall be chosen with increasing compressive strain and ductility of the material.

6.1.2 Preferred test specimens

The preferred dimensions for test specimens are given in Table 2.

Table 2 — Dimensions of preferred specimen types

Dimensions in millimetres

Type	Measurement	Length, l	Width, b	Thickness, h
A	Modulus	50 ± 2	10 ± 0,2	4 ± 0,2
B	Strength	10 ± 0,2		

The specimens should preferably be cut from a multipurpose test specimen (see ISO 3167).

NOTE Annex A details two types of small test specimen for use when, owing to lack of material or because of geometric constraints on a product, the preferred specimen types cannot be used.

6.2 Preparation

6.2.1 Moulding and extrusion compounds

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

6.2.2 Sheets

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

6.2.3 Machining

All machining operations shall be carried out carefully so that smooth surfaces result. Great care shall be taken in machining the ends so that smooth, flat, parallel surfaces and sharp, clean edges, perpendicular to the longest axis of the specimen to within 0,025 mm, result.

It is recommended that the end surfaces of the test specimen be machined with a lathe or a milling machine.

6.2.4 Gauge marks

If optical equipment is used to measure the change in length, it is necessary to put gauge marks on the specimen to define the gauge length. These shall be approximately equidistant from the midpoint of the test specimen, and the distance between the marks shall be measured to an accuracy of 1 % or better.