INTERNATIONAL STANDARD

ISO 604

Third edition
2002-03-01

Plastics — Determination of compressive properties

Plastiques — Détermination des propriétés en compression

Reference number
ISO 604:2002(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.ch
Web www.iso.ch

Printed in Switzerland

Contents

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 (ε_2 = 0,002 5 minus ε_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.

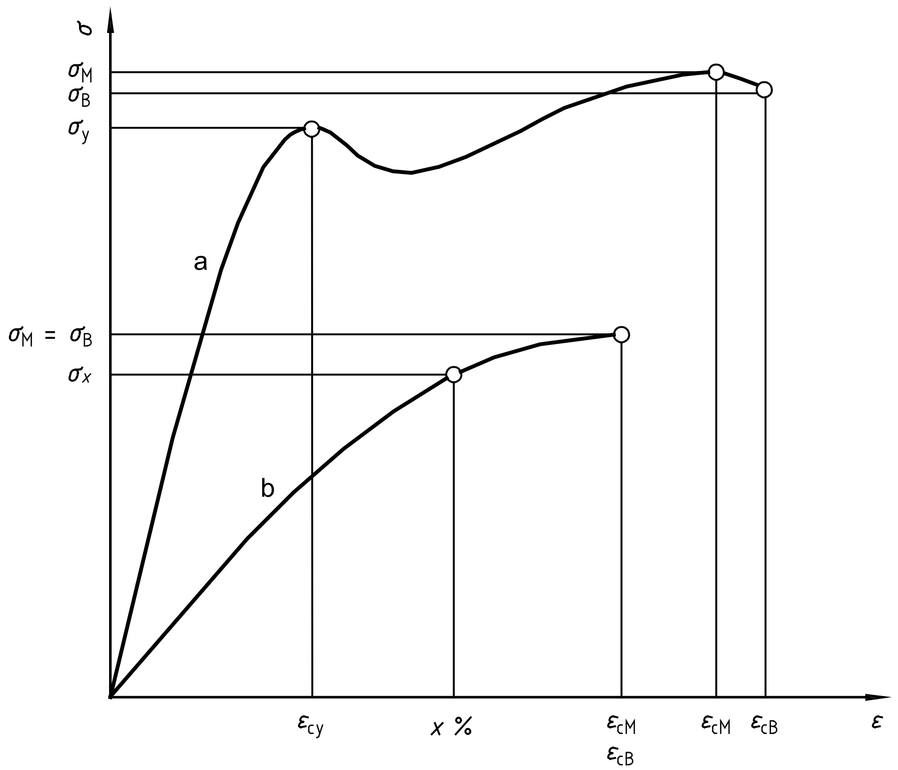


Figure 1 — Typical stress/strain curves

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):

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

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.

Gauge marks shall not be scratched, punched or impressed upon the test specimen in any way which causes damage to the material being tested. It shall be ensured that the marking medium has no detrimental effect on the material being tested and that they are as narrow as possible.

6.3 Specimen inspection

The specimens shall be free of twist. The surfaces and edges shall be free from scratches, pits, sink marks, flash and other visible imperfections that are likely to influence the results. The surfaces facing the compression plates shall be parallel and at right angles to the longitudinal direction.

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 departure 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 side faces of moulded test specimens will generally not be parallel.

6.4 Anisotropic materials

6.4.1 In the case of anisotropic materials, the test specimens shall be chosen so that the compressive stress will be applied in the test procedure in the same or a similar direction to that experienced by the products (moulded articles, sheet, tubes, etc.) during service in the intended application, if known.

6.4.2 The relationship between the dimensions of the test specimen and the size of the product will determine the possibility of using preferred test specimens. If the use of one of the preferred test specimens is impossible, the size of the product will govern the choice of the dimensions of the test specimens as well as 6.1. It should be noted that the orientation and dimensions of the test specimens sometimes have a very significant influence on the test results.

6.4.3 When the material shows a significant difference in compressive properties in two principal directions, it shall be tested in these two directions. If, because of its intended application, the material will be subjected to compressive stress at some specific orientation other than one of the principal directions, it is desirable to test the material in that orientation.

The orientation of the test specimens relative to the principal directions shall be recorded.

7 Number of test specimens

7.1 Test at least five specimens for each sample in the case of isotropic materials.

7.2 Test at least ten specimens, five normal to and five parallel to the principal axis of anisotropy, for each sample in the case of anisotropic materials.

7.3 Specimens that break at some obvious flaw shall be discarded and replacement specimens tested.

8 Conditioning of test specimens

The test specimens shall be conditioned in accordance with the requirements of the International Standard for the material. In the absence of such requirements, use the most appropriate conditions given in ISO 291, unless otherwise agreed between the interested parties.

The preferred set of conditions is atmosphere 23/50, except when the compressive properties of the material are known to be insensitive to moisture, in which case humidity control is unnecessary.

9 Test procedure

9.1 Test atmosphere

Perform the test in one of the standard atmospheres specified in ISO 291, preferably the same atmosphere as used for conditioning.

9.2 Measurement of test specimen dimensions

Measure the width and thickness, or the diameters, of the test specimen at three points along its length and calculate the mean value of the cross-sectional area.

Measure the length of each test specimen to 1 % accuracy.

9.3 Set up

Place the test specimen between the surfaces of the compression plates and align the centrelines of the compression plate surfaces. Ensure that the end surfaces of the specimen are parallel to the surfaces of the compression plates and adjust the machine so that the surfaces of the ends of the test specimen are just touching the compression plates.

During compression, the end surfaces of the test specimen may slip along the compression plates to varying extents, depending upon the surface textures of the specimen and plates. This will lead to varying degrees of barrel distortion, which in turn may influence the values of the properties measured. The less rigid the material, the more pronounced the effect.

For the most precise measurements, it is recommended that either the end surfaces be treated with an appropriate lubricant to promote slip or that discs of fine abrasive paper be used between specimen and plates to inhibit slip. If either method is used, it shall be noted in the test report.

9.4 Preload

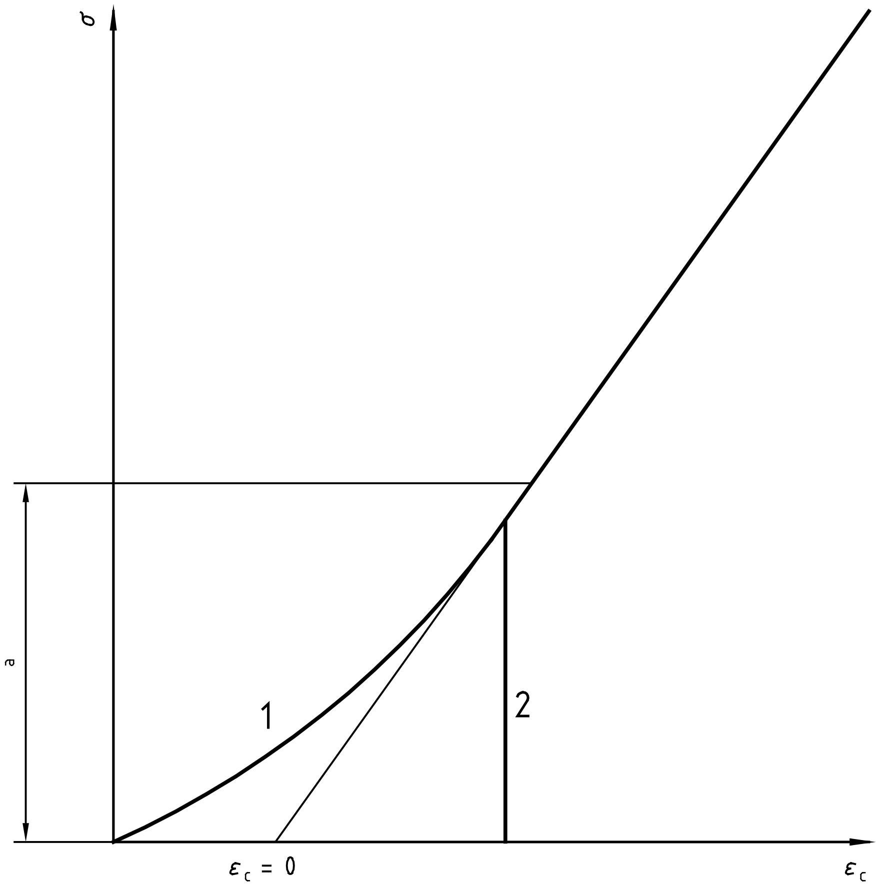
The specimen shall not be loaded substantially prior to the test. Such loads may be necessary, however, to avoid a curved region at the start of the stress/strain diagram. For modulus measurement, the compressive stress σ_0 at the start of a test (see Figure 2) shall lie within the range:

$$0 \leqslant \sigma_0 \leqslant 5 \times 10^{-4} E_c \quad (2)$$

which corresponds to a prestrain of $\varepsilon_{c0} \leqslant 0{,}05$ %, and when measuring characteristics such as σ_M it shall lie within the range:

$$0 \leqslant \sigma_0 \leqslant 10^{-2} \sigma_M \quad (3)$$

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



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 $\leqslant 5 \times 10^{-4} E_c$ or $\leqslant 10^{-2} \sigma_M$

Figure 2 — Example of stress/strain curves with an initial curved region and with a step, and determination of zero-strain point

9.5 Test speed

Set the test speed v (see 3.2), in millimetres per minute, to the value specified by the material specification or, in the absence of this, to that of the values given in Table 1 which is the closest approximation to

$v = 0{,}02l$ (l in millimetres) for modulus measurements;

$v = 0{,}1l$ (l in millimetres) for strength measurements with materials which break prior to yielding;

$v = 0{,}5l$ (l in millimetres) for strength measurements with materials which yield.

For the preferred test specimens (see 6.1.2), the test speeds are

1 mm/min for modulus measurements (l = 50 mm);

1 mm/min for strength measurements with materials which break prior to yielding (l = 10 mm);

5 mm/min for strength measurements with materials which yield (l = 10 mm).

9.6 Recording of data

Determine the force (stress) and the corresponding compression (strain) of the specimen during the test. It is preferable to use an automatic recording system which yields a complete stress/strain curve for this operation.

Determine all relevant stresses and strains defined in clause 3 from the stress/strain data recorded during the test.

If a curved region is found in the initial part of the stress/strain diagram, check that it does not extend beyond the prestress limit given in 9.4. See annex C for a method of compliance correction if compression was not measured directly on the test specimen.

10 Calculation and expression of results

10.1 Stress

Calculate the stress parameters defined in 3.3, using the following equation:

$$\sigma = \frac{F}{A} \tag{4}$$

where

σ is the stress parameter in question, expressed in megapascals;

F is the force measured, expressed in newtons;

A is the initial cross-sectional area of the specimen, expressed in square millimetres.

10.2 Strain

10.2.1 Strain (as measured by extensometry)

Calculate the strain parameters defined in 3.4, using the following equations:

$$\varepsilon = \frac{\Delta L_0}{L_0} \tag{5}$$

$$\varepsilon \text{ (in \%)} = 100 \times \frac{\Delta L_0}{L_0} \tag{6}$$

where

ε is the strain parameter in question, expressed as a dimensionless ratio (equation 5) or as a percentage (equation 6);

L_0 is the gauge length of the test specimen, expressed in millimetres;

ΔL_0 is the decrease in the specimen length between the gauge marks, expressed in millimetres.

10.2.2 Nominal strain (as determined by crosshead travel)

Calculate the nominal-strain parameters defined in 3.5, using the following equations:

$$\varepsilon_c = \frac{\Delta L}{L} \tag{7}$$

$$\varepsilon_c \text{ (in \%)} = 100 \times \frac{\Delta L}{L} \tag{8}$$

where

ε_c is the nominal strain in question, expressed as a dimensionless ratio (equation 7) or as a percentage (equation 8);

L is the initial distance between the compression plates, expressed in millimetres;

ΔL is the decrease in the distance between the compression plates.

If ΔL is not measured directly between the compression plates by a suitable displacement transducer, but by using e.g. the crosshead movement of the test machine, corrections for machine compliance shall be applied to the determination of ΔL (see annex C).

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 stress described in 9.4 (see Figure 2).

10.3 Compressive modulus

Calculate the compressive modulus, defined in 3.6, on the basis of two specified strain values determined in accordance with 10.2.1:

$$E_c = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \tag{9}$$

where

E_c is the compressive modulus, expressed in megapascals;

σ_1 is the stress, in megapascals, measured at the value of the strain ε_1 of 0,000 5;

σ_2 is the stress, in megapascals, measured at the value of the strain ε_2 of 0,002 5.

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

10.4 Statistical parameters

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

10.5 Significant figures

Calculate the stresses and the compressive modulus to three significant figures. Calculate the strains to two significant figures.

11 Precision

The precision of this test method is not known because interlaboratory data are not available. When interlaboratory data are obtained, a precision statement will be added at the following revision.

12 Test report

The test report shall include the following information:

a) a reference to this International Standard, plus the type of specimen and the test speed, in accordance with the following scheme:

Compressive test — ISO 604 / A / 1

Type of specimen — A

Test speed in millimetres per minute — 1

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

c) a description of the nature and form of the material under test, i.e. whether it is a product, semi-finished product, test plate or specimen, and including principal dimensions, shape, method of manufacture, order of layers, preliminary treatment, etc.;

d) the specimen width, thickness and length, giving the mean, minimum and maximum values, if applicable;

e) details of the method used to prepare the test specimens;

f) if the material is in the form of a finished or semi-finished product, the orientation of the specimen in relation to the finished or semi-finished product from which it was cut;

g) the number of specimens tested;

h) the atmosphere used for conditioning and for testing, plus any special conditioning treatment carried out if required by the International Standard for the material or product;

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

j) the type of extensometer used;

k) the type of compression tool used;

l) whether or not slip promoters or slip inhibitors were used on the end surfaces;

m) the individual test results determined for the compressive properties defined in clause 3;

n) the mean value of each of the properties measured, quoted as the indicative value(s) for the material tested;

o) (optional) the standard deviation and/or coefficient of variation and/or confidence limits of the mean;

p) whether any test specimens were rejected and replaced and, if so, the reasons;

q) the date of the test.

Annex A
(normative)

Small test specimens

A.1 Test specimens as specified in clause 6 may be impossible to produce from the amount of material available or from a finished product. In these circumstances, use may be made of the small specimens described in this annex.

A.2 It must be expected that the results obtained with small specimens will differ from those obtained with normal-sized specimens.

A.3 The use of small specimens shall be agreed to by the interested parties, and specific reference to their use made in the test report.

A.4 The test shall be carried out in accordance with this International Standard as for normal test specimens, except as noted below.

The nominal dimensions of the specimens, in millimetres, shall be as specified in Table A.1.

Table A.1 — Nominal dimensions of small test specimens

Dimensions in millimetres

Dimension	Type 1	Type 2
Thickness	3	3
Width	5	5
Length	6	35

The type 2 specimen shall only be used for determining compressive modulus; in this case the use of a 15 mm gauge length is recommended to facilitate the determination.

Annex B
(informative)

Limits of buckling

According to Euler, the critical axial compressive force F^* for the onset of buckling of a specimen of length l fixed at both ends, assuming linear stress/strain behaviour of the material under test, is given by:

$$F^* = \frac{\pi^2 E_c I}{l^2} \tag{B.1}$$

where

F^* is the critical buckling load, in newtons;

I is the second moment of inertia of the cross-sectional area, in millimetres to the power of 4;

E_c is the compressive modulus, in newtons per square millimetre;

l is the specimen length, in millimetres.

The critical force can be replaced by the corresponding nominal strain at buckling in accordance with equation (B.2):

$$F^* = E_c A \varepsilon_b \tag{B.2}$$

where

A is the cross-sectional area, in square millimetres;

ε_b is the nominal compressive strain at buckling (dimensionless).

This gives the critical buckling strain, which depends only upon the dimensions of the specimen, in accordance with equation (B.3):

$$\varepsilon_b = \pi^2 \times \frac{I}{Al^2} \tag{B.3}$$

For the different types of specimen shape, equation (B.3) can be expressed as follows:

a) For a right prism:

$$\varepsilon_b = \frac{\pi^2}{12} \times \left(\frac{h}{l}\right)^2 \tag{B.4}$$

b) For a right cylinder or tube:

$$\varepsilon_b = \frac{\pi^2}{4} \times \left(\frac{r}{l}\right)^2 \times \left[l + \left(\frac{r_i}{r}\right)^2\right] \tag{B.5}$$

where

l is the length of the right prism, cylinder or tube, i.e. the dimension parallel to the compressive force, in millimetres;

h is the thickness of the right prism, i.e. the smallest side of the cross-section, in millimetres;

r is the radius of the cylinder or the outer radius of the tube, in millimetres;

r_i is the inner radius of the tube (zero for a cylinder), in millimetres.

The additional stability of the tube compared to the cylinder as shown by equation (B.5) cannot be used, as thin-walled tubes fail in accordance with additional buckling modes not discussed here. The numerical factors used in equations (B.4) and (B.5) equal 0,8 and 0,6 respectively. As these equations give only a rough estimate of the buckling strain, they approximate to the general inequality (1) in 6.1.1, in which the numerical factor chosen has been decreased to avoid buckling.

Annex C
(normative)

Compliance correction

If the decrease ΔL in the distance between the compression plates cannot be measured directly and has to be replaced by precisely recording the displacement s between the crossheads of the test machine, this difference in displacement shall be corrected for the compliance C_M of the machine (see note 1). C_M is determined using a parallel-sided strip or prism of highly rigid reference material of known compressive modulus (see note 2), e.g. from steel sheet. The deflection s is calculated using the equations

$$\Delta L = s - C_M F \tag{C.1}$$

and

$$C_M = \frac{s_R}{F} - \frac{L_R}{(b_R d_R) E_{cR}} \tag{C.2}$$

where

ΔL is the decrease in the distance between the compression plates, in millimetres;

s 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_{cR} is the compressive modulus, in megapascals, of the reference material;

L_R is the initial distance, in millimetres, between the compression plates;

b_R is the width, in millimetres, of the reference specimen;

d_R is the thickness, in millimetres, of the reference specimen.

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

NOTE 1 Three parts of the test machine contribute to its compliance C_M, the largest contribution commonly being that from the grips, the second largest that from the force transducer and the smallest that from the frame of the machine.

NOTE 2 For the stresses encountered during the determination of machine compliance, it can be assumed that the compressive modulus of the reference material is identical to the tensile modulus.

Bibliography

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

[2] ISO 3597-3:1993, *Textile-glass-reinforced plastics — Determination of mechanical properties on rods made of roving-reinforced resin — Part 3: Determination of compressive strength*

[3] ISO 7616:1986, *Cellular plastics, rigid — Determination of compressive creep under specific load and temperature conditions*

[4] ISO 7743:1989, *Rubber, vulcanized or thermoplastic — Determination of compression stress-strain properties*

[5] ISO 14126:1999, *Fibre-reinforced plastic composites — Determination of compressive properties in the in-plane direction*

ICS 83.080.01

Price based on 18 pages