INTERNATIONAL STANDARD

ISO 604

Second edition
1993-06-15

Plastics — Determination of compressive properties

Plastiques — Détermination des propriétés en compression

Reference number
ISO 604:1993(E)

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.

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.

International Standard ISO 604 was prepared by Technical Committee ISO/TC 61, *Plastics*, Sub-Committee SC 2, *Mechanical properties*.

This second edition cancels and replaces the first edition (ISO 604:1973), which has been improved with respect to the following points:

— introduction of the compressive modulus;

— simplification with respect to the buckling limit;

— introduction of preferred specimen types, which relate to the multipurpose test specimen according to ISO 3167;

— introduction of three preferred testing speeds, for measuring the modulus and for testing brittle and tough materials respectively.

Annex A forms an integral part of this International Standard. Annex B is for information only.

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Plastics — Determination of compressive properties

1 Scope

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

1.2 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.

1.3 The method applies to the following range of materials:

— rigid and semirigid thermoplastics 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 semirigid thermoplastic sheet;

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

— thermotropic liquid crystal polymers.

The method is not normally suitable for use with materials reinforced by textile fibres, rigid cellular materials and sandwich structures containing cellular material.

1.4 The method is performed using specimens which may be either moulded to the chosen dimensions, machined from the central portion of the standard multipurpose test specimen (see ISO 3167) or machined from finished and semifinished products such as mouldings, laminates and 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 speed of testing and the conditioning of the specimens, can also influence the results. Consequently, when comparative data are required, these factors should be carefully controlled and recorded.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 293:1986, *Plastics — Compression moulding test specimens of thermoplastic materials.*

ISO 294:—[1)], *Plastics — Injection moulding of test specimens of thermoplastic materials.*

ISO 295:1991, *Plastics — Compression moulding of test specimens of thermosetting materials.*

ISO 472:1988, *Plastics — Vocabulary.*

ISO 1268:1974, *Plastics — Preparation of glass fibre reinforced, resin bonded, low-pressure laminated plates or panels for test purposes.*

1) To be published. (Revision of ISO 294:1975)

ISO 2602:1980, *Statistical interpretation of test results — Estimation of the mean — Confidence interval.*

ISO 2818:—[2], *Plastics — Preparation of test specimens by machining.*

ISO 3167:1993, *Plastics — Multipurpose test specimens.*

ISO 5893:1985, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Description.*

3 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.

4 Definitions

For the purposes of this International Standard, the following definitions apply (see also figure 1):

4.1 gauge length, L_0: Initial distance between the gauge marks on the test specimen.

It is expressed in millimetres (mm).

4.2 speed of testing, v: Rate of approach of the plates of the testing machine during the test.

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

4.3 compressive stress, σ (engineering): Compressive load, per unit area of original cross-section, carried by the test specimen (see note 3).

It is expressed in megapascals (MPa).

4.3.1 compressive stress at yield, σ_y: First stress at which an increase in strain (see 4.4) occurs without an increase in stress; may be less than the maximum attainable stress (see figure 1, curve a, and note 3).

4.3.2 compressive strength, σ_M: Maximum compressive stress sustained by the test specimen during a compressive test (see figure 1 and note 3).

4.3.3 compressive stress at break (rupture), σ_B: Compressive stress at break of the test specimen (see figure 1 and note 3).

4.3.4 compressive stress at x **% strain,** σ_x: Stress at which the strain reaches a specified value of x % (see 4.5).

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 3). In this case, x shall be taken from the relevant product standard or agreed upon by the interested parties. However, in any case, x must be lower than the strain at compressive strength.

4.4 compressive strain, ε: Decrease in length per unit original length of the gauge L_0 [see 8.2, equation (3) and note 3].

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

4.5 nominal compressive strain, ε_c: Decrease in length per unit original length l of the test specimen [see 8.2, equation (4)].

It is expressed as a dimensionless ratio and may be specified directly or as a percentage of the initial length.

4.5.1 nominal compressive yield strain, ε_{cy}: Strain corresponding to the compressive yield stress σ_y (see 4.3.1).

4.5.2 nominal compressive strain at compressive strength, ε_{cM}: Strain corresponding to the compressive strength σ_M (see 4.3.2).

4.5.3 nominal compressive strain at break, ε_{cB}: Strain at break of the test specimen.

4.6 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 8.3, equation (7)].

It is expressed in megapascals, MPa.

NOTES

1 The compression modulus is calculated on the basis of the compressive strain ε only (see 4.4).

2 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 on the part of the curve between these mentioned points.

3 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 unnecessary for the nominal compressive strains ε_c.

2) To be published. (Revision of ISO 2818:1980)

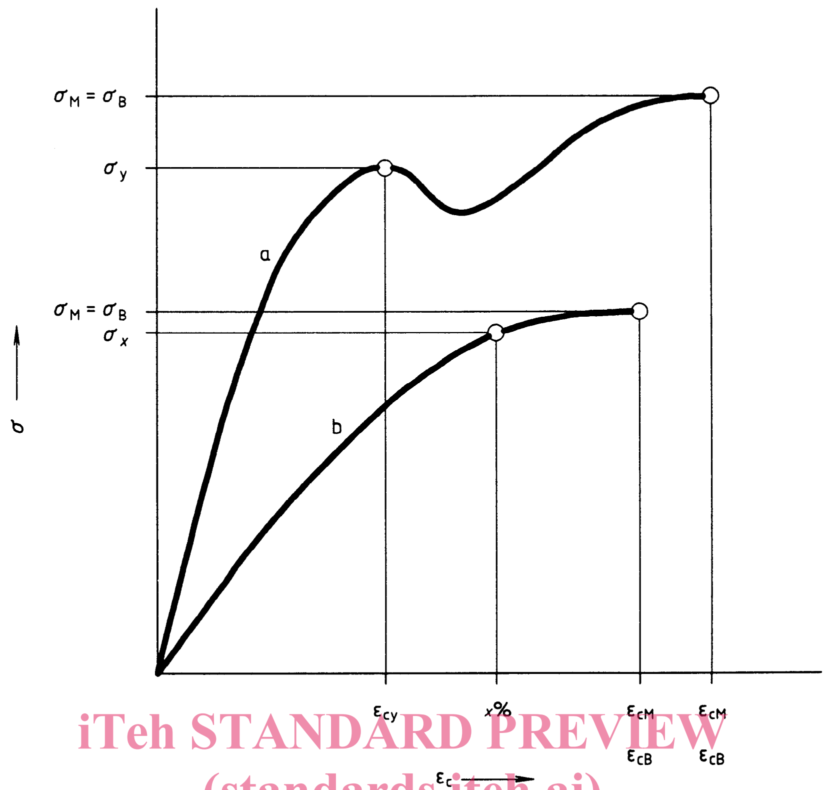

Figure 1 — Typical stress/strain curves

5 Apparatus

5.1 Testing machine

The testing machine shall be power-driven and capable of maintaining the appropriate speed of testing as specified in 7.5. The machine shall satisfy the conditions given in ISO 5893. The testing machine shall be equipped with the devices described in 5.1.1 to 5.1.3.

5.1.1 Compression tool, of hardened steel compression plates, for applying the deformation to the test specimen, so constructed that the load carried by the specimen is axial within 1:1 000 and transmitted through polished surfaces which are flat within 0,025 mm and parallel to each other in a plane normal to the loading axis.

NOTE 4 A self-aligning device may be used where required.

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

5.1.3 Deformation indicator, suitable for determining the change in length of the appropriate part of the test specimen. If compressive strain ε is to be measured (preferred), 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. This instrument shall be essentially free of inertia lag at the specified testing speed and shall be accurate to ± 1 % or better of the relevant value.

When a deformation indicator 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 deformation indicator and the test specimen.

5.2 Devices for measuring the dimensions of the test specimens

5.2.1 For rigid materials, use a micrometer or equivalent, reading to at least 0,01 mm, for measuring the thickness, width and length.

5.2.2 For semirigid materials, use a micrometer or equivalent, reading to at least 0,01 mm and provided with a flat circular foot which applies a pressure of 20 kPa ± 3 kPa, for measuring thickness.

6 Test specimens

6.1 Preparation

Prepare test specimens in accordance with the requirements of the International Standard for the material concerned. In the absence of such requirements, the most appropriate method taken from the list of International Standards in clause 2 shall be used, unless otherwise agreed by the interested parties.

All surfaces of the test specimens shall be free from visible flaws, scratches and other imperfections that are likely to influence the results.

6.2 Shape

The test specimen shall be in the shape of a right prism, cylinder or tube. 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, to within 0,025 mm perpendicular to the longest axis of the specimen, result.

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

The dimensions of the test specimens shall meet the conditions in equation (1) (see annex B).

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

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 smaller side of the cross-section) of the prism, depending on the shape of the test specimen.

NOTES

5 For measurement of the compressive modulus E_c according to 4.6, the dimension ratio $x/l \geqslant 0{,}08$ is recommended.

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

7 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 should be chosen with increasing compressive strain and ductility of the material.

6.3 Preferred test specimens

The preferred dimensions for test specimens are given in table 1.

Table 1 — 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 ± 0,2
B	strength	$10\ ^{+0}_{-2}$		

Preferably the specimens are to be cut from a multipurpose test specimen (see ISO 3167).

NOTE 8 Annex A details two types of small test specimen for use when, for reasons of lack of material or geometric constraints for a product, the preferred specimens cannot be used.

6.4 Gauge marks

If optical deformation indicators are used, 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 must be ensured that the marking medium has no detrimental effect on the material being tested and that, in the case of two pairs of parallel lines, they are as narrow as possible.

6.5 Anisotropic materials

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

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 the preferred test specimen is impossible, the size of the product will govern the choice of dimensions of the test specimens in accordance with

6.2 as well. It should be noted that the orientation and the dimensions of the test specimens sometimes have a very significant influence on the test results. This is particularly true of laminates.

6.5.2 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 destined application, this material will be subjected to compressive stress at some specific orientation to the principal direction, it is desirable to test the material in that orientation.

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

6.6 Number of test specimens

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

6.6.2 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.

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

6.7 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 shall be made of the most appropriate conditions given in ISO 291, unless otherwise agreed by the interested parties.

The preferred condition 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.

7 Test procedure

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

7.2 Measure the width and thickness, or the diameter(s), 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.

7.3 Place the test specimen between the surfaces of the compression plates and align the centreline 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 and compression plate are just touching.

NOTE 9 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 properties to be 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.

7.4 Attach the deformation indicator, if required.

7.5 Set the speed of testing v in millimetres per minute (see 4.2) in accordance with the material specification or, in the absence of this, to that of the following value:

$1 \pm 0,2$

$2 \pm 0,4$

5 ± 1

10 ± 2

20 ± 2

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 brittle materials, which break prior to yielding;

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

For the preferred test specimens (see 6.3) the testing speeds are

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

1 mm/min for strength measurements with brittle materials ($l = 10$ mm);

5 mm/min for strength measurements with ductile materials ($l = 10$ mm).

7.6 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.

7.7 Determine all relevant stresses and strains compiled in clause 4 (definitions) from the stress/strain curve or by other suitable means.

7.8 The modulus, as defined in 4.6, may be determined from the stress/strain curve, provided that the stress and strain scales are sufficiently expanded.

8 Calculation and expression of results

8.1 Stress calculations

Calculate all stress values defined in 4.3 on the basis of the original cross-sectional area of the test specimen:

$$\sigma = \frac{F}{A} \qquad \ldots (2)$$

where

σ is the compressive stress value in question, in megapascals;

F is the measured force in question, in newtons;

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

8.2 Strain calculations

Calculate the compressive strain defined in 4.4 on the basis of the gauge length defined in 4.1 using the equations:

$$\varepsilon = \frac{\Delta L}{L_0} \qquad \ldots (3)$$

$$\varepsilon\ (\%) = 100 \times \frac{\Delta L}{L_0} \qquad \ldots (4)$$

The nominal compressive strain, defined in 4.5, is calculated on the basis of the initial specimen length l using the equations:

$$\varepsilon_c = \frac{\Delta l}{l} \qquad \ldots (5)$$

$$\varepsilon_c\ (\%) = 100 \times \frac{\Delta l}{l} \qquad \ldots (6)$$

where

ε is the compressive strain, expressed as a dimensionless ratio or in percent;

ε_c is the nominal compressive strain, expressed as a dimensionless ratio or in percent;

L_0 is the initial distance between the gauge marks (gauge length) on the test specimen, expressed in millimetres;

ΔL is the decrease in the specimen length between the gauge marks, expressed in millimetres;

l is the initial specimen length, expressed in millimetres;

Δl is the decrease in the specimen length, expressed in millimetres.

8.3 Modulus calculation

Calculate the compressive modulus, defined in 4.6, using equation (7):

$$E_c = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \qquad \ldots (7)$$

where

E_c is the compressive modulus of elasticity, expressed in megapascals;

σ_1 is the compressive stress calculated according to equation (2), in megapascals, measured at the strain value ε_1;

σ_2 is the compressive stress calculated according to equation (2), in megapascals, measured at the strain value ε_2;

ε_1 is the compressive strain calculated according to equation (3) or (4), having the value $\varepsilon_1 = 0{,}000\,5$ or 0,05 %;

ε_2 is the compressive strain calculated according to equation (3) or (4), having the value $\varepsilon_2 = 0{,}002\,5$ or 0,25 %.

8.4 Statistical parameters

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

8.5 Significant figures

Calculate the compressive stress and modulus to three significant figures. Calculate the compressive strain to two significant figures.

9 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 with the next revision.

10 Test report

The test report shall include the following information:

a) a reference to this International Standard, including the type of specimen and the testing speed according to

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Compressive test                                    ISO 604 / A / 1
Type of specimen (see table 1) ─────────────────────────┘   │
Testing speed, in millimetres per minute (see 7.5) ─────────┘
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b) 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 in terms of whether it is a product, semifinished product, test plate or specimen. It should include principal dimensions, shape, method of manufacture, order of layers, preliminary treatments, etc.;

d) type of test specimen, width, thickness and length: mean, minimum and maximum values, if applicable;

e) method of preparing the test specimen and any details of the manufacturing method used;

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

g) number of specimens tested;

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

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

j) type of deformation indicator;

k) type of compression tool;

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

m) the speed of testing;

n) the individual test results;

o) the mean value(s) x of the measured property(ies), quoted as the indicative value(s) for the material tested;

p) (optionally) the standard deviation SD, and/or coefficient of variation, and/or confidence limits of the mean;

q) if any test specimens have been rejected and replaced, and if so, the reasons;

r) date of measurement.