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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for compressive behaviour of continuous fibre-reinforced composites at room temperature

Céramiques techniques — Méthode d'essai de résistance à la compression des composites renforcés de fibres continues à température ambiante

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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

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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 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 20504 was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for compressive behaviour of continuous fibre-reinforced composites at room temperature

1 Scope

This International Standard describes procedures for determination of the compressive behaviour of ceramic matrix composite materials with continuous fibre reinforcement at room temperature. This method applies to all ceramic matrix composites with a continuous fibre reinforcement, uni-directional (1D), bi-directional (2D) and tri-directional (xD, with $2 < x \leqslant 3$), tested along one principal axis of reinforcement. This method may also be applied to carbon-fibre-reinforced carbon matrix composites (also known as: carbon/carbon or C/C). Two cases of testing are distinguished: compression between platens and compression using grips.

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 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 3611, *Micrometer callipers for external measurements*

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

ISO 14126, *Fibre-reinforced plastic composites — Determination of compressive properties in the in-plane direction*

ASTM E1012, *Standard Practice for Verification of Test Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application*

3 Terms and definitions

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

3.1
gauge section
part of the test specimen which has uniform and minimum cross-sectional area

3.2
gauge section length
l
length of the gauge section

3.3
initial gauge length
L_o
initial distance between reference points on the test specimen in the gauge section before initiation of the test

3.4
final gauge length
L_f
final distance between reference points on the test specimen in the gauge section at the completion of the test

3.5
initial cross-sectional area
A_o
initial area of the gauge section's cross-section

3.6
longitudinal deformation
ΔL
change (contraction) of the initial gauge due to the application of a uniaxial compressive force

NOTE The longitudinal deformation corresponding to the maximum force should be denoted as $\Delta L_{c,m}$.

3.7
compressive strain
ε
relative change in the gauge length defined as the ratio $\Delta L/L_o$

NOTE The compressive strain corresponding to the maximum force is denoted as $\varepsilon_{c,m}$.

3.8
compressive force
F_c
uniaxial compressive force applied to a test specimen

3.9
maximum compressive force
$F_{c,m}$
greatest uniaxial compressive force applied to a test specimen when tested to failure

3.10
compressive stress
σ
compressive force supported by the test specimen at any time in the test divided by the initial cross-sectional area such that $\sigma = F_c/A_o$

3.11
compressive strength
$S_{c,m}$
greatest compressive stress applied to a test specimen when tested to failure

3.12
proportionality ratio or pseudo-elastic modulus
E_p
slope of the linear region of the stress-strain curve, if any

NOTE Examination of the stress-strain curves for ceramic matrix composites allows definition of the following cases:

— Material with a linear region in the stress-strain curve.

For ceramic matrix composites that have a mechanical behaviour characterised by a linear region, the proportionality ratio E_p is defined as:

$$E_p(\sigma_1, \sigma_2) = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \quad (1)$$

where (ε_1, σ_1) and (ε_2, σ_2) lie near the lower and the upper limits of the linear region of the stress-strain curve (see Figures A.1 and A.2).

— Material with non-linear region in the stress-strain curve. In this case only, stress-strain couples can be determined at specified stresses or specified strains.

3.13
elastic modulus
E
proportionality ratio or pseudo-elastic modulus, in the special case where the linearity starts near the origin

See Figure A.2.

3.14
axial strain
average of the longitudinal strain measured at the surface of the test specimen at specified locations

See Annex B.

3.15
bending strain
difference between the longitudinal strain at a given longitudinal location on the test specimen surface and the axial strain at the same location

See Annex B.

3.16
buckling force
critical axially applied force at which an initially straight column assumes a curved shape

3.17
critical buckling stress
critical axial compressive stress at which an initially straight column assumes a curved shape

4 Principle

A test specimen of specified dimensions is loaded in compression. The compression test is usually performed at a constant cross-head displacement rate or at a constant deformation rate.

NOTE Constant force rate is only allowed in the case of linear stress-strain behaviour up to failure.

For cross-head displacement tests, a constant rate is recommended when the test is conducted to failure.

The force and longitudinal deformation are measured and recorded simultaneously.

5 Apparatus

5.1 Test machine

The machine shall be equipped with a system for measuring the force applied to the test specimen that shall conform to grade 1 or better in accordance with ISO 7500-1.

5.2 Load train

The load train is composed of movable and fixed cross-heads, the loading rods and the grips or platens. Load train couplers may additionally be used to connect the grips or platens to the loading rods.

The load train shall align the test specimen axis with the direction of force application without introducing bending or torsion in the test specimen. The misalignment of the test specimen shall be verified and documented in accordance with the procedure described in Annex B. The maximum percent bending shall not exceed 5 % at an average axial strain of 500×10^{-6}.

There are two alternative means of force application:

a) Compression platens are connected to the force transducer and the moving cross-head. The parallelism of these platens shall be better than 0,01 mm, in the loading area and the faces of the platens shall be perpendicular to the force application direction.

   NOTE 1 The use of platens is not recommended for compression testing of 1D and 2D materials with small thicknesses because of buckling.

   NOTE 2 A compliant interlayer material (composed only of paper or cardboard), between the test specimen and platens, can be used for testing macroscopically inhomogeneous materials to ensure uniform contact pressure.

   When the dimensions of the test specimen are such that buckling may occur, it is recommended to use antibuckling devices similar to those described in ISO 14126. These devices should not introduce parasitic stresses (i.e. stresses other than the uniform, axial stress) during loading of the test specimen.

b) Grips are used to clamp and load the test specimen. The grip design shall prevent the test specimen from slipping and the grips shall align the test specimen axis with that of the applied force.

Alignment shall be verified and documented in accordance with, for example, the procedure described in Annex B.

5.3 Strain measurement

5.3.1 General

For continuous measurement of the longitudinal deformation as a function of the applied force, either strain gauges or a suitable extensometer may be used. Use an extensometer that meets the requirements of at least class 1 in ISO 9513. Measurement of longitudinal deformation over a length as long as possible within the gauge section length of the test specimen is recommended.

5.3.2 Strain gauges

Strain gauges are used for the verification of the alignment on the test specimen. They may also be used to determine longitudinal deformation during testing. In both cases, the length of the strain gauges shall be such that the readings are not affected by local features on the surface of the specimen, such as fibre crossovers. Unless it can be shown that strain gauge readings are not unduly influenced by localized strain events, such as fibre crossovers, strain gauges should be not less than 9 mm to 12 mm in length for the longitudinal direction and not less than 6 mm in length for the transverse direction. The strain gauges, surface preparation and bonding agents/adhesives should be chosen to provide adequate performance on the subject materials.

Suitable strain-conditioning and recording equipment should be used. Care shall be taken to ensure that the strain gauge readings are not influenced by the surface preparation and the adhesive used.

5.3.3 Extensometry

The linearity tolerance of the extensometer shall be less than 0,15 % of the extensometer range used. Extensometers shall meet the requirements of at least class 1 in accordance with ISO 9513.

Types of commonly used extensometers are described in 5.3.3.1 and 5.3.3.2.

5.3.3.1 Mechanical extensometer

For a mechanical extensometer, the gauge length corresponds to the longitudinal distance between the two locations where the extensometer contacts the test specimen. Mounting of the extensometer to the test specimen shall prevent slippage of the extensometer at the contact points and shall not initiate failure under the contact points. Any extensometer contact forces shall not introduce bending greater than that allowed in 5.2.

5.3.3.2 Electro-optical extensometer

Electro-optical measurements of strain require reference marks on the test specimen. For this purpose, fiducial marks such as rods or flags are attached to the test specimen surface perpendicular to the longitudinal axis of the test specimen. The gauge length corresponds to the longitudinal distance between the two fiducial marks.

NOTE The use of integral flags as part of the test specimen geometry is not recommended, because of stress concentrations induced by such features.

5.4 Data recording system

A calibrated recorder may be used to record force-deformation curves. The use of a digital data recording system combined with an analog recorder is recommended.

5.5 Dimension measuring devices

Devices used for measuring linear dimensions of the test specimen shall be accurate to ± 0,1 mm. Micrometers shall be in accordance with ISO 3611.

6 Test specimens

6.1 General

The choice of test specimen geometry depends on several parameters:

- the nature of the material and of the reinforcement structure;
- the type of testing system.

The ratio between the length of the test specimen subject to buckling and the thickness of the test specimen, in addition to the stiffness of the material, will influence the resistance of the test specimen to buckling.

If buckling occurs, it may be necessary to modify the dimensions of the test specimen or alternatively to use an antibuckling device (e.g. fixed lateral guides pressed against the test specimen so as to freely allow longitudinal motion while simultaneously suppressing transverse motion).

The volume in the gauge length shall be representative of the material.

Two types of test specimens can be distinguished.

a) As-fabricated test specimens, where only the length and the width are machined to the specified size. In this case, the two faces of the test specimen may present irregular surfaces while the two edges present regular machined surfaces.

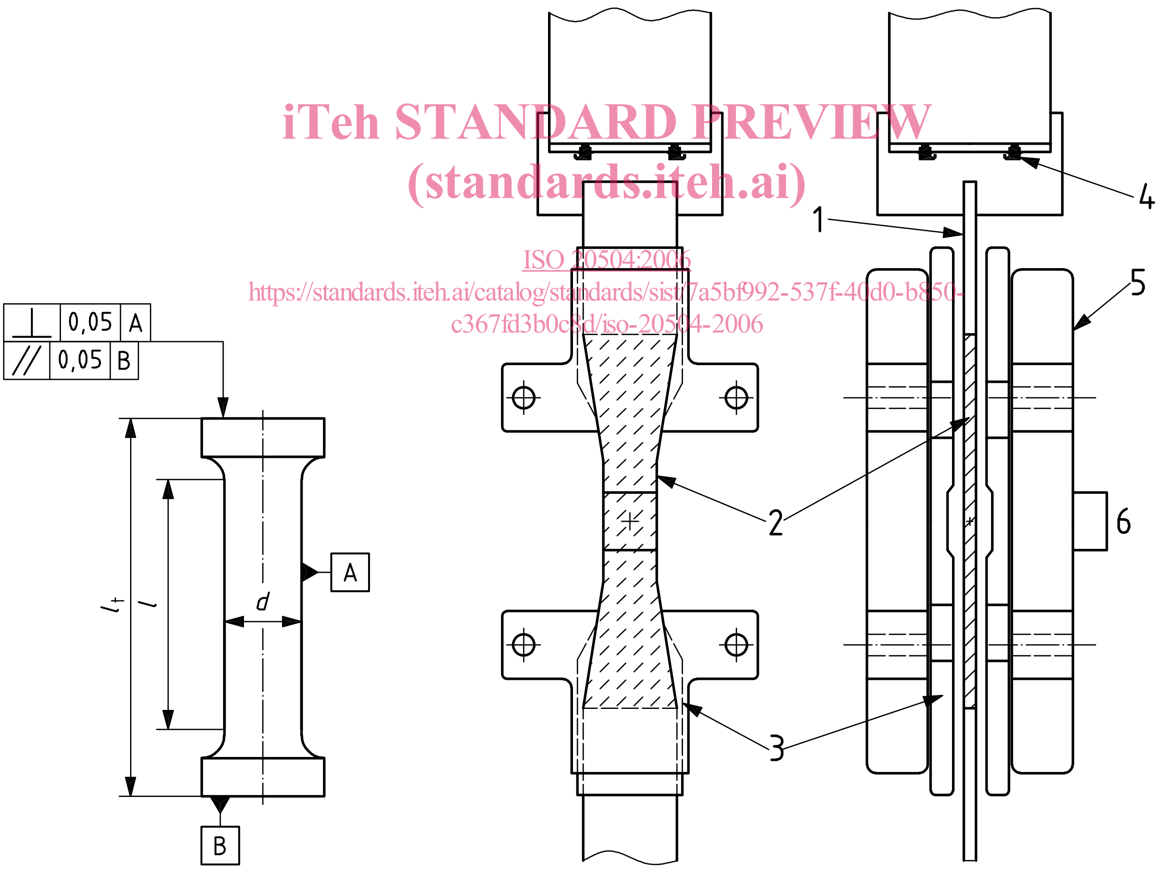
b) Machined test specimens, where the length and the width, as well as the two faces of the test specimen, have been machined and present regular machined surfaces.

Tolerance on the thickness dimension only applies to machined test specimens. For as-fabricated test specimens, the difference in thickness out of three measurements (at the centre and at each end of the gauge section length) should not exceed 5 % of the average of the three measurements.

6.2 Compression between platens

The test specimen geometry and/or compliant interlayers may be adapted in order to avoid buckling and damage at the edges due to contact forces.

Type 1 is commonly used and is illustrated in Figure 1. Recommended dimensions are given in Table 1.



a) **Test specimen**

b) **Example of anti-buckling guides**

Key

1 loading anvil
2 specimen
3 lateral support
4 O-ring
5 frame
6 unsupported length

Figure 1 — Compression test specimen (type 1) used between platens and anti-buckling guides

Table 1 — Dimensions for compression test specimen (type 1) used between platens

Dimensions in millimetres

Parameter	1D, 2D, xD	Tolerance
l, gauge section length	⩾ 15	± 0,5
l_t, total length	⩾ 1,5 × l mm	± 0,5
d, cylindrical or square-section side length or diameter	⩾ 8	± 0,2
Parallelism of machined parts	0,05	N/A
Perpendicularity of machined parts	0,05	N/A
Concentricity of machined parts	0,05	N/A

Type 2 is cylindrical in shape and is not used as frequently as type 1. It is illustrated in Figure 2 and recommended dimensions are given in Table 2.

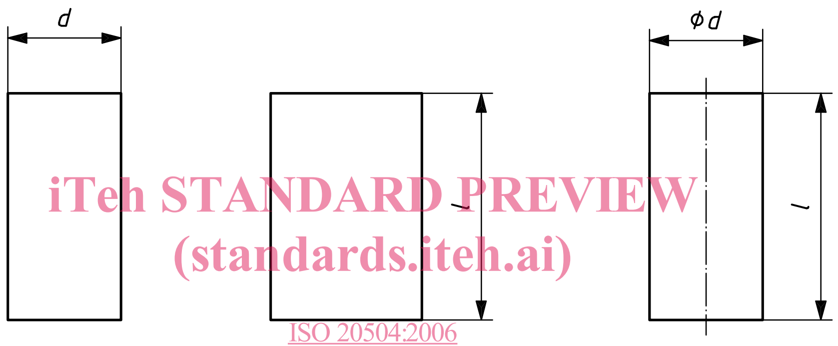


Figure 2 — Compression test specimen (type 2) used between platens

Table 2 — Dimensions for compression test specimen (type 2) used between platens

Dimensions in millimetres

Parameter	1D, 2D, xD	Tolerance
l, gauge section length	⩾ 10	± 0,5
d, cylindrical or square-section	⩾ 10	± 0,2
Parallelism of machined parts	0,05	N/A
Perpendicularity of machined parts	0,05	N/A
NOTE This test specimen is mainly used when the thickness of the part is not sufficient to machine a test specimen of type 1.		

6.3 Test specimen used with grips

For these types of test specimens, the total length l_t depends on the gripping system. These types of test specimens allow testing of thin test specimens without using an anti-buckling device. It is, however, necessary to verify that the chosen l/h ratio does not lead to buckling.