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**Fine ceramics (advanced ceramics,  
advanced technical ceramics) —  
Test method for flexural strength  
of monolithic ceramic thin plates at  
room temperature by three-point or  
four-point bending**

*Céramiques techniques — Méthode d'essai de la résistance en flexion  
des plaques minces en céramique monolithique à température  
ambiante en flexion trois ou quatre points*

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## Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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

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

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

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# Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for flexural strength of monolithic ceramic thin plates at room temperature by three-point or four-point bending

## 1 Scope

This document describes a test method for the flexural strength of monolithic ceramic thin plates at room temperature by three-point bending or four-point bending.

This document is intended for use with monolithic ceramics and whisker- or particulate-reinforced ceramics which are regarded as macroscopically homogeneous. It does not include continuous-fibre-reinforced ceramics composites. This document is applicable to ceramic thin plates with a thickness from 0,2 mm to 1,0 mm.

This document is for material development, material comparison, quality assurance, characterization and reliability data generation.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1101, *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 3611, *Geometrical product specifications (GPS) — Dimensional measuring equipment: Micrometers for external measurements — Design and metrological characteristics*

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 14704:2016, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for flexural strength of monolithic ceramics at room temperature*

## 3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

### 3.1

#### flexural strength

maximum nominal stress at fracture of a specified elastic plate loaded in bending

**3.2 three-point flexure**

configuration of flexural strength testing where a specimen is loaded at a location midway between two support bearings

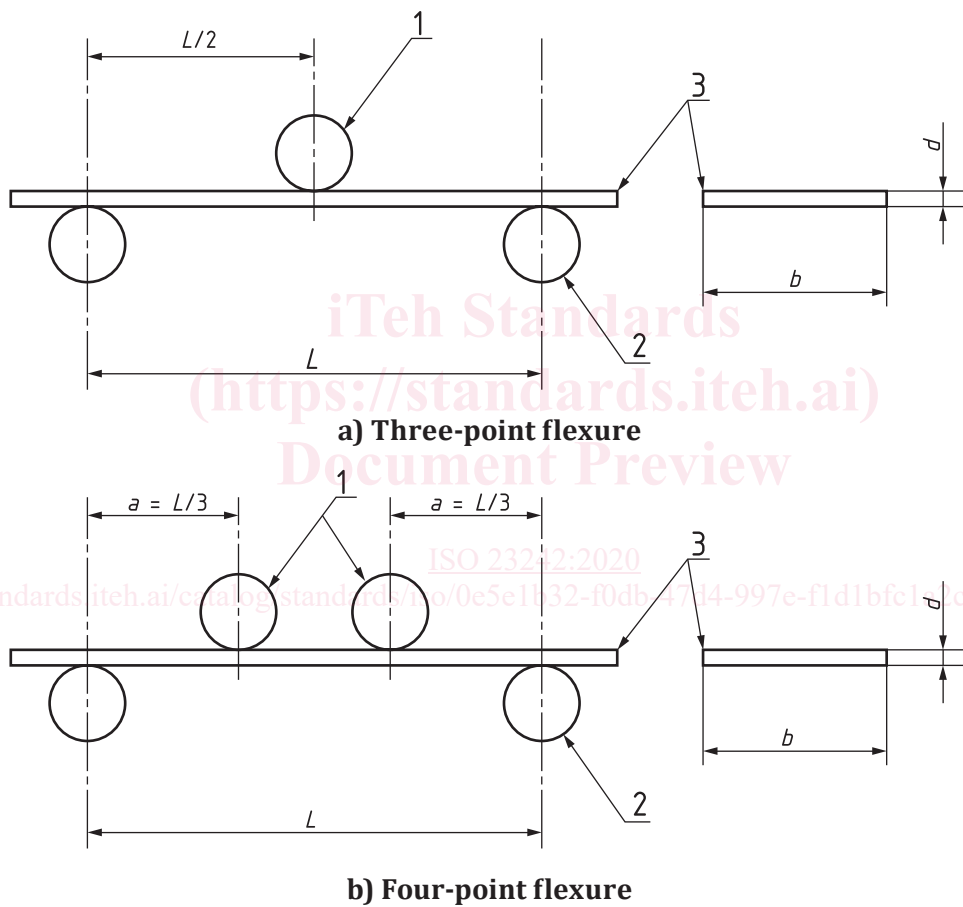
Note 1 to entry: See [Figure 1 a\)](#) and [Table 1](#).

Note 2 to entry: The bearings may be cylindrical rollers or cylindrical bearings.

**3.3 four-point flexure**

configuration of flexural strength testing where a specimen is loaded equally by two bearings located symmetrically between two support bearings

Note 1 to entry: See [Figure 1 b\)](#) and [Table 1](#).



**Key**

- 1 loading bearing(s)
- 2 support bearings
- 3 specimen

**Figure 1 — Flexural test configurations**

Table 1 — Specimen type and dimension of bend test fixtures

Specimen type	Specimen thickness $d$ mm	Bending mode	Lower span $L$ mm	Length of fixture moment arm	Diameter of bearings mm
				$a$ mm	
I	$0,5 \leq d \leq 1,0$	3-point	$30 \pm 0,1$	—	4,5 to 5,0
I	$0,5 \leq d \leq 1,0$	4-point	$30 \pm 0,1$	$10 \pm 0,1$	4,5 to 5,0
II	$0,2 \leq d < 0,5$	3-point	$15 \pm 0,1$	—	4,5 to 5,0
II	$0,2 \leq d < 0,5$	4-point	$15 \pm 0,1$	$5 \pm 0,1$	2,5 to 3,0

### 3.4

#### fully articulating fixture

test fixture designed to apply uniform and even loading to test specimens that can have uneven, non-parallel or twisted surfaces

### 3.5

#### semi-articulating fixture

test fixture designed to apply uniform and even loading to specimens that have flat and parallel surfaces

## 4 Principle

A plate specimen with a rectangular cross-section is loaded in flexure until fracture. The load at fracture, the test fixture and specimen dimensions are used to compute the flexural strength of the specimen, which is a measure of the uniaxial tensile strength of a ceramic. The material is assumed to be isotropic and linearly elastic.

## 5 Apparatus

### 5.1 Bend testing machine

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A suitable testing machine capable of applying a uniform crosshead speed shall be used. The testing machine shall be in accordance with ISO 7500-1, with an accuracy of 1 % of the indicated force at fracture. The test load of ceramic thin samples ranges roughly between 20 N and 200 N. A load cell shall be selected so that the fracture load of thin plates is not close to the limits of load capacity interval, i.e. the lower limit for high-load cell capacity and the upper limit for low-load cell capacity.

### 5.2 Bend test fixture

#### 5.2.1 General

Three- or four-point flexure configurations shall be used, as illustrated in [Figure 1](#) and Table 1. The fixture shall have bearings that are free to roll, as described in [5.2.2](#), in order to eliminate frictional constraints when the specimen surfaces expand or contract during loading. In addition, the fixture shall be designed so that parts “articulate” or tilt to ensure uniform loading to the specimen. The articulation shall be designed so that parts of the fixture can rotate, as specified in ISO 14704:2016, Figure B.1, to ensure even loading on the left and right bearings. An articulation is also needed to ensure that all the bearings contact the specimen surfaces evenly and apply a uniform load. Semi-articulated fixtures have some articulating or tilting capabilities and may be used with specimens that have flat and parallel surfaces, such as those of machined specimens. A semi-articulating fixture shall have pairs of upper and lower bearings that articulate to match the specimen surfaces, as specified in ISO 14704:2016, Figures B.2 and B.3. Fully articulated fixtures have more moving parts and shall be used for specimens that do not have flat and parallel surfaces. They allow independent articulation of the bearings. Fully articulated fixtures are often necessary for as-fired, heat-treated or oxidized specimens, since uneven loading can cause twisting and severe errors. A fully articulating fixture may also be used with

machined specimens. For further detail on both semi-articulating and fully articulating fixtures, refer to ISO 14704.

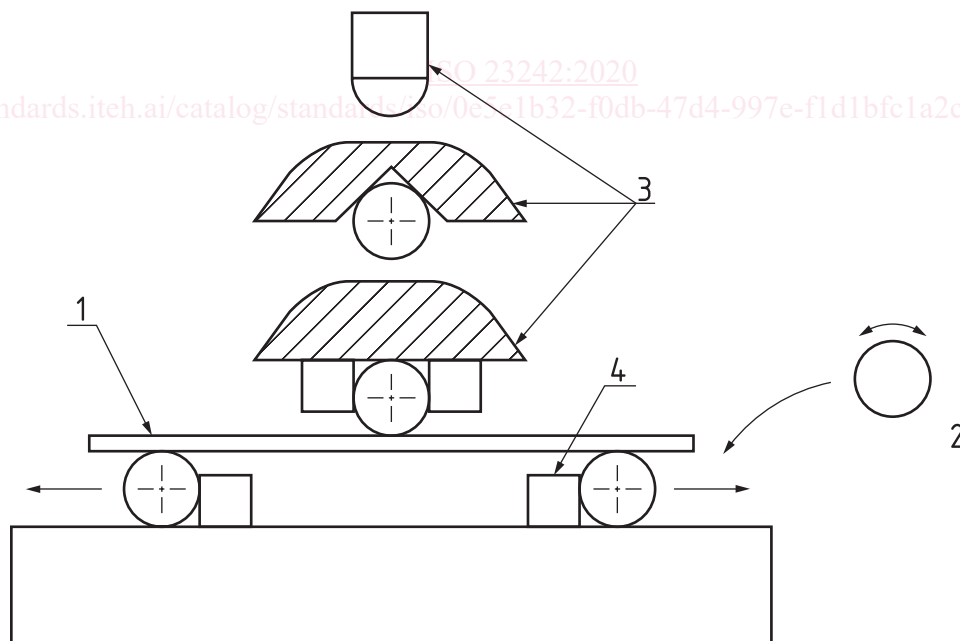
**5.2.2 Bearings**

Specimens shall be loaded and supported by bearings. The bearings may be cylindrical rollers or cylindrical pins. The bearings shall be made of a steel which has a hardness of no less than HRC 40 for specimen strengths up to 1 400 MPa, or no less than HRC 46 for specimen strengths up to 2 000 MPa. Alternatively, the bearing may be made of a ceramic or a hard metal with an elastic modulus between 200 GPa and 500 GPa and a flexural strength greater than 275 MPa. The bearing length shall be greater than or equal to 35 mm. The bearing diameter shall be between 4,5 mm and 5 mm, except that samples with a thickness of less than 0,5 mm are bent in a four-point bending. When samples with a thickness of less than 0,5 mm are bent in a four-point configuration, the bearing diameter shall be between 2,5 mm and 3 mm. The bearings shall have a smooth surface and shall have a diameter that is uniform to  $\pm 0,015$  mm. The bearings shall be free to roll in order to eliminate friction, as shown in Figure 2. In four-point flexure, the two inner bearings shall be free to roll inward, and the two outer bearings shall be free to roll outward. In three-point flexure, the two outer bearings shall be free to roll outward, and the inner (middle) bearing shall not roll.

**5.2.3 Positioning of bearings**

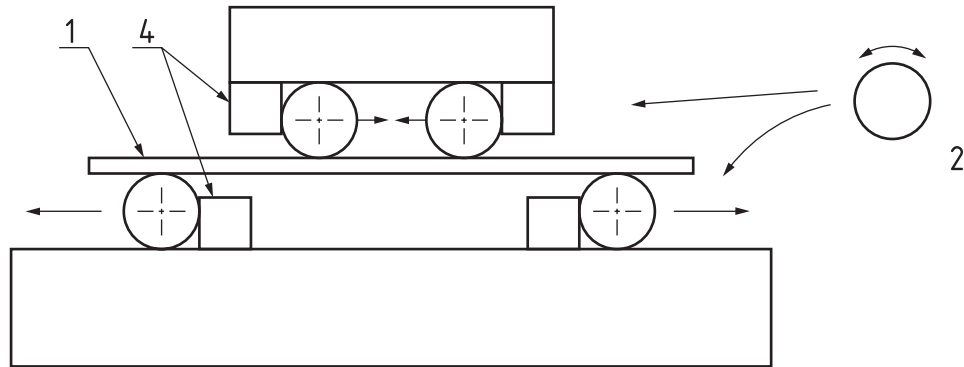
Bearings shall be positioned so that their spans are accurate to within  $\pm 0,1$  mm. The middle bearing in a three-point fixture shall be positioned midway between the outer bearings to within  $\pm 0,1$  mm. The inner bearings in a four-point fixture shall be centred over the outer bearings to within  $\pm 0,1$  mm.

NOTE The positions of the bearings can be defined either by the use of captive bearings or by appropriate stops against which the bearings are held at the commencement of a test. The spans can be measured to the nearest 0,1 mm using a travelling microscope or other suitable device. The spans can also be verified by measuring the distances between bearing stops and adding (outer span) or subtracting (inner span) the radii of the bearing cylinders.



**a) Three-point flexure**





b) Four-point flexure

**Key**

- 1 specimen
- 2 alternative rolling bearings
- 3 alternative loading arrangements
- 4 stops

**Figure 2 — Schematic illustration of fixtures showing rolling action of bearings and stops****5.2.4 Fixture material**

The fixture which supports and aligns the bearings shall be of sufficient hardness to prevent the bearings from deforming the fixture permanently.

**5.3 Calibrated micrometer**

The calibrated micrometer shall be similar to one in accordance with ISO 3611 but capable of being read to a precision of 0,002 mm using a vernier or electronic readout. The micrometer shall have flat anvil faces. A micrometer with a ball tip or sharp tip shall not be employed due to its potential to introduce surface flaws into the specimen. An alternative measuring apparatus may be used, provided that it has a resolution of 0,002 mm or finer.

**5.4 Metallurgical microscope**

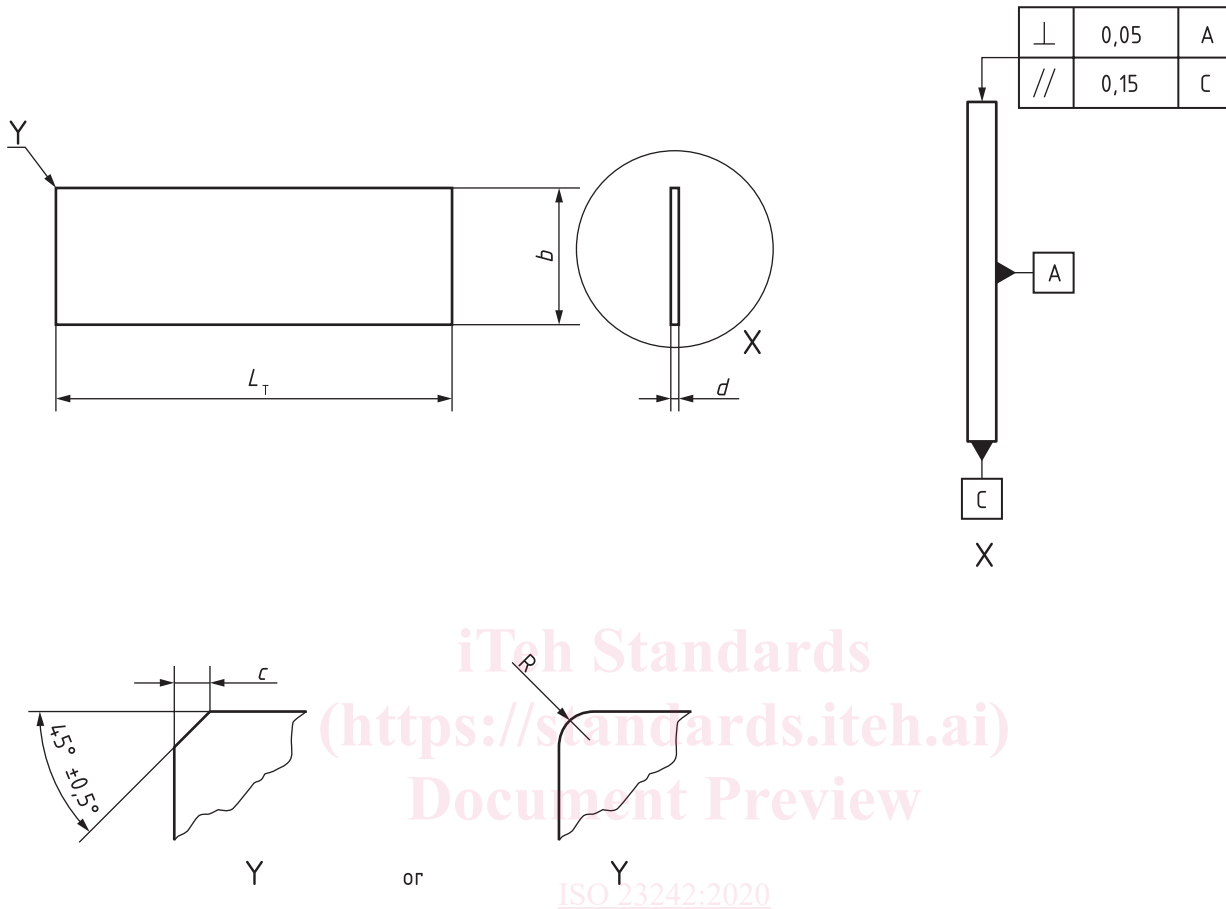
A metallurgical microscope equipped with a photomicrographic capability or a measuring microscope shall be used to observe and measure chamfering of test piece edges.

**6 Test piece dimension and preparation****6.1 Shape and dimensions of test piece****6.1.1 Machined specimens**

Test piece dimensions are shown in [Figure 3](#). The parallelism tolerance on the opposite longitudinal side face  $L \times d$  shall be 0,15 mm as defined in ISO 1101. The longitudinal side faces shall intersect with the large faces perpendicularly. The maximum variation in perpendicularity shall not exceed 0,05 mm. Variation of thickness  $d_{\max} - d_{\min}$  shall be less than 10 % of the average thickness  $d_{\text{avg}}$ , which is determined from the thicknesses at three or more points.

6.1.2 As-fired specimens

Specimen dimensions may be altered as required, but deviations from the specifications in 6.1.1 and Figure 3 shall be stated in a test report.



Specimen type	Specimen thickness $d$ mm	Total length $L_T$ mm	Width $b$ mm	Chamfering $c$ mm	Rounded edge $R$ mm
I	$0,5 \leq d \leq 1,0$	$\geq 35$	$12 \pm 0,2$	0,05 to 0,13	0,05 to 0,13
II	$0,2 \leq d < 0,5$	$\geq 20$	$12 \pm 0,2$	0,05 to 0,1	0,05 to 0,1

Figure 3 — Dimensions of specimen

6.2 Test piece preparation

6.2.1 General

This document allows several options for specimen preparation. All four long edges shall be chamfered or rounded as shown in Figure 3. It is highly recommended that the surface roughness be measured and reported, although a surface finish specification is not part of this document.

NOTE Machining damage can be introduced during surface preparation of test specimens (especially microcracks beneath the specimen surface) and can have an extensive effect on flexural strength. Machining flaws can be either a random interfering factor or an inherent part of the strength characteristics to be measured. Surface preparation can also create residual stresses. Final machining steps (including polishing) can negate machining damage introduced from prior, coarser machining steps.