INTERNATIONAL STANDARD

ISO 15732

First edition
2003-09-01

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for fracture toughness of monolithic ceramics at room temperature by single edge precracked beam (SEPB) method

Céramiques techniques — Méthode d'essai de ténacité à la rupture des céramiques monolithiques à température ambiante sur éprouvette préfissurée sur une seule face (méthode SEPB)

Reference number
ISO 15732:2003(E)

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

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

Published in Switzerland

Contents

Page

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 15732 was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for fracture toughness of monolithic ceramics at room temperature by single edge precracked beam (SEPB) method

1 Scope

This International Standard describes a test method for the determination of fracture toughness of monolithic ceramic materials at room temperature by the Single Edge Precracked Beam (SEPB) method.

This International Standard is intended for use with monolithic ceramics and whisker- or particulate-reinforced ceramics which are regarded as macroscopically homogeneous. It does not include continuous-fiber-reinforced ceramic composites.

This International Standard is for material development, material comparison, quality assurance, characterization, reliability and design data generation.

Fracture toughness values determined with other test methods cannot be interchanged with K_{Ipb} as defined in this International Standard, and may not be interchangeable with each other.

Values expressed in this International Standard are in accordance with the International System of Units (SI).

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 1101:1983, *Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Generalities, definitions, symbols, indications on drawings*

ISO 3312:1987, *Sintered metal materials and hardmetals — Determination of Young modulus*

ISO 4287:1997, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 6507-1:1997, *Metallic materials — Vickers hardness test — Part 1: Test method*

3 Terms and definitions

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

3.1
stress intensity factor
K_I
magnitude of the elastic stress field singularity at the tip of a crack subjected to opening mode displacement

NOTE It is a function of applied force and test specimen size, geometry and crack length, and has the dimensions of force times length$^{-3/2}$.

3.2
fracture toughness
generic term for the magnitude of resistance to crack extension

3.3
fracture toughness value
K_{Ipb}
fracture toughness value measured by the SEPB method

NOTE This represents the measured stress intensity factor corresponding to the extension resistance of a straight-through pop-in crack formed via bridge loading of a Vickers indent or a saw notch. The measurement is performed in accordance with the operational procedure described in Clauses 5 and 10 and satisfies all the validity requirements.

3.4
precrack
crack induced artificially into a specimen, primarily so as to measure the fracture toughness

3.5
precrack front line
line to indicate the position of the tip of the precrack

3.6
pop-in
phenomenon where a crack arrests after sudden and unstable growth giving rise to an acoustic signature

3.7
three-point bending
loading configuration where a beam specimen is loaded at a location midway between two support pins

3.8
four-point bending
loading configuration where a beam specimen is symmetrically loaded at two locations that are situated one quarter of the overall span away from the outer two support pins

3.9
compliance
reciprocal of the gradient of the load versus deflection curve

NOTE Accordingly, as the crack extends, the increase of deflection results in an increase of compliance.

4 Symbols and designations

The symbols used throughout this International Standard and their designations are given in Table 1.

Table 1 — Symbols and designations

Symbol	Unit	Designation	References
b	mm	Width of central groove in anvil	A.2.3, Fig. A.1
d	mm	Thickness of specimen	7.1, Fig. 3
d_1	mm	Distance between supporting roller pins in bend test fixture (lower span)	6.4, Fig. 2
d_2	mm	Distance between loading roller pins in four-point bend test fixture (upper span)	6.4, Fig. 2
K_{Ipb}	$\mathrm{MPa \cdot m^{1/2}}$	Critical stress intensity factor measured by the SEPB method	Clause 10, Eqs. 7 and 10
l	mm	Length of precrack	8.7.3, Fig. 6, Eq. 2
Δl	mm	Stable crack growth length	8.7.4, Fig. 6, Eq. 3
L	mm	Length of specimen	7.1, Fig. 3
L_{a}	mm	Length of bottom surface of specimen positioning groove of anvil (including the width, b, of central groove)	A.2.3, Fig. A.1
L_{p}	mm	Length of lower surface of loading plate	A.2.3, Fig. A.1
P_{f}	N	Maximum load during fracture of specimen	8.5.3, Fig. 5
w	mm	Width (depth) of specimen	7.1, Fig. 3
$\lambda \Delta l$ / λl	1	Compliance change	8.6, Eq. 1

5 Principle

This method is to obtain the fracture toughness value, K_{Ipb}, from the precrack length, specimen dimensions and distance between the bending supports by measuring the fracture load of specimen according to the three or four-point bending fracture test of a single-edge-precracked beam specimen. A straight-through pop-in precrack is induced in the specimen via bridge loading of a Vickers indent or a saw notch. Generally, this test is carried out under conditions of ambient temperature and environment.

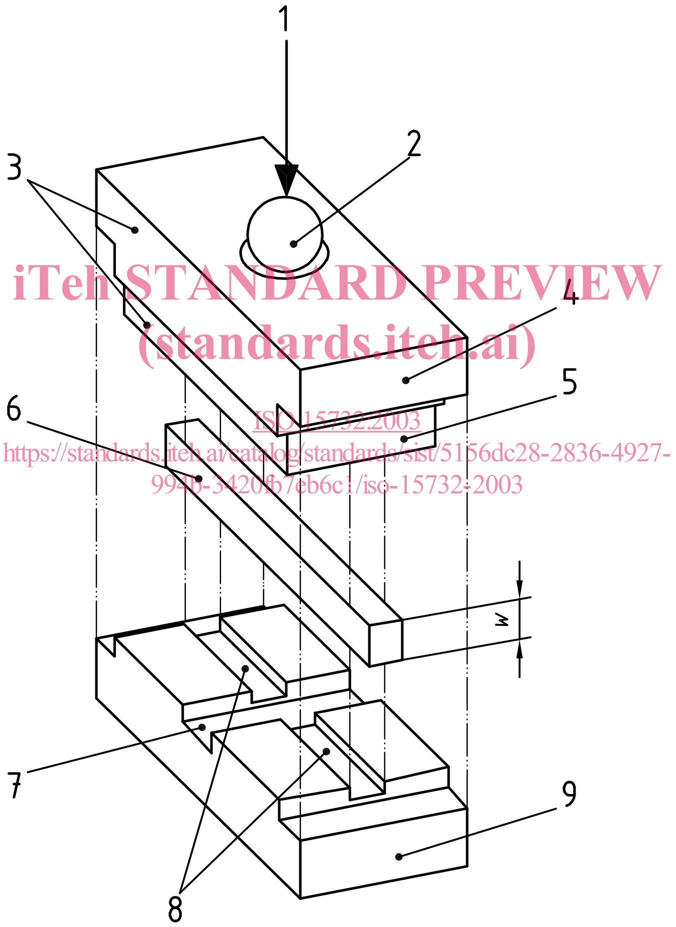
6 Apparatus

6.1 Precracking fixture

An appropriate apparatus is required to induce a pop-in precrack in the specimen in such a way that the crack front is approximately parallel to the specimen surface.

An example of the basic components of the bridge compression precracking fixture are a loading plate with a ball seat, an anvil with a central groove and a specimen-positioning groove, and a loading ball as shown in Figure 1. The shapes of the loading plate and the anvil to be used are symmetric from right to left, and from front to rear, and have depth exceeding at least three times the thickness of the specimen, d. The horizontal distance between the centre of the loading ball and the centre of the anvil is less than 0,1 mm.

NOTE Annex A contains recommendations for the typical design of a suitable bridge compression fixture that has been found to work satisfactorily for most types of ceramic materials.



Key

1 compression load
2 loading ball
3 loading plate
4 upper loading plate; e.g., of hardened steel with ball seat
5 lower loading plate; e.g., of silicon nitride with mirror polished lower surface (joined to upper loading plate)
6 specimen
7 central groove
8 specimen positioning groove
9 anvil; e.g., of hardened steel (HV 10 > 5 GPa)

Figure 1 — Example of bridge compression precracking fixture

6.2 Precrack introduction loading apparatus

The loading apparatus shall be capable of smoothly applying the compression load to the fixture. High load accuracy is not required.

6.3 Bend testing machine

A material testing machine capable of maintaining the cross-head-speed constant shall be used. The accuracy of load measurement shall be ± 1 % over the entire range of load.

The rigidity of the entire testing system, including the bending test fixture specified in 6.4, shall be 3 MN/m or more against the load applied to the bending test fixture.

The rigidity of the entire testing system, including the testing machine, loading rods and bending test fixture, should be evaluated in accordance with Annex B.

6.4 Bend test fixture

The general features of the bend test fixtures are illustrated in Figure 2. The bend test fixture shall be symmetrical about the centre line shown and have a depth exceeding at least three times the thickness, d, of the specimen to be used. The fixture is designed to minimize frictional effects by allowing the support roller to roll apart slightly as the specimen is loaded, thus permitting rolling contact and avoiding frictional wedging of the specimen.

The roller pins are placed in the positioning grooves of the support member and of the loading member as shown in Figure 2. The rollers shall be parallel to each other to within 0,015 mm over a length equal to the specimen thickness, d. Other types of fixtures are acceptable, however, roller pins shall be free to roll. The length of each roller pin shall be equal to at least three times the specimen thickness. Materials composing the parts of the roller pins to be used shall have a modulus of elasticity not less than 196 GPa, as defined in ISO 3312 and a hardness of not less than 5 GPa Vickers (HV10) as defined in ISO 6507-1, and made of a material free from plastic deformation and risk of fracture. The radius of curvature of rollers and the distance between the rollers shall be as shown in Figure 2. The surface roughness of the rollers, Ra, as defined in ISO 4287 shall be not more than 0,4 µm.

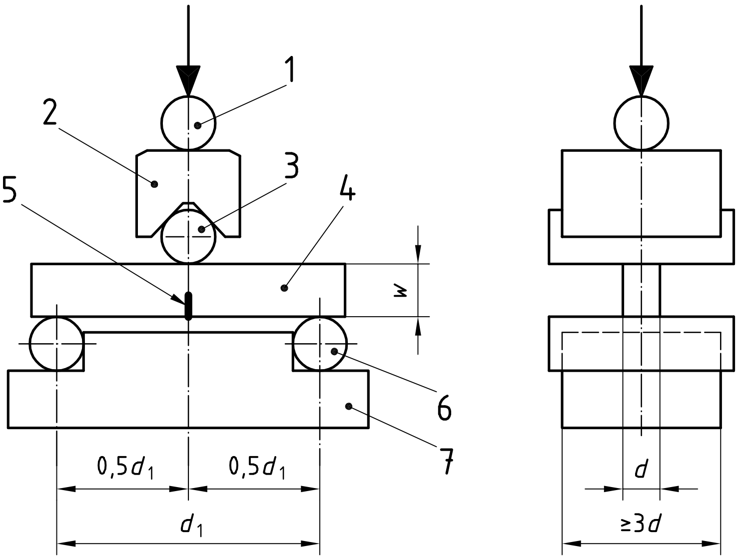
6.5 Compliance change measuring device

At the time of the bend test, the relation between the deflection of the test specimen and the load shall be measured by using the deflection meter which can measure the load point deflection between the centre of two supporting roller pins of the bend test fixtures and the centre of loading roller pin(s). The deflection measuring device shall have a resolution greater than 0,001 mm, and shall be calibrated to read within 0,001 mm of the true displacement. Measurements of displacement shall be made to a precision of 0,001 mm.

6.6 Measuring instruments

Three fundamental measurements are necessary for the calculation of K_{Ipb}, namely, the width, w, the thickness, d, and the precrack length, l.

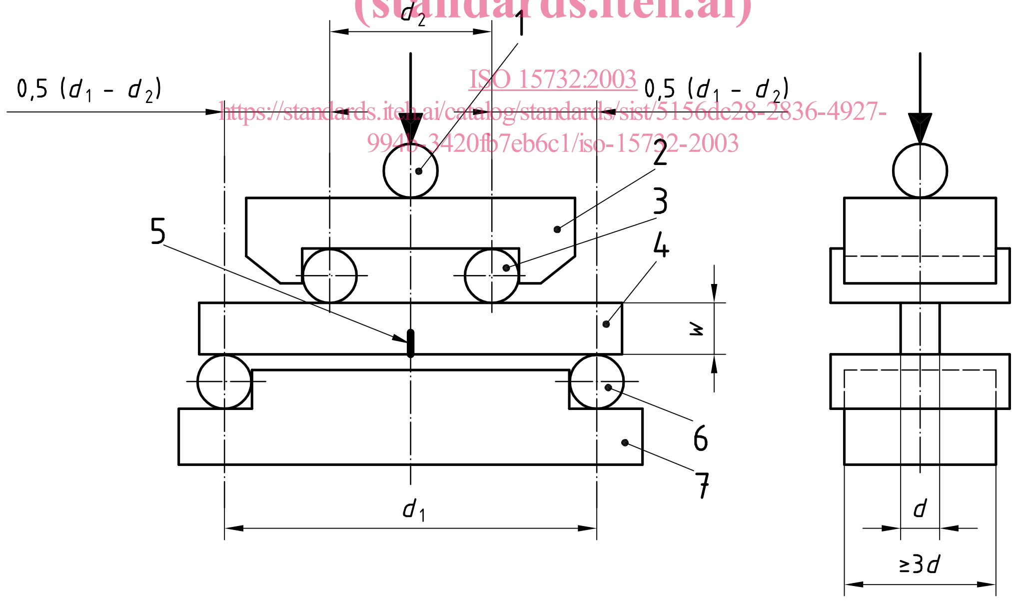
Measuring devices such as micrometers or other devices having an accuracy of at least 0,01 mm shall be used for measuring the linear dimensions.



Key

1 loading ball
2 loading member
3 loading roller pin
4 specimen (I or II)
5 precrack
6 supporting roller pins
7 support member

a) Three-point bend test fixture



Key

1 loading ball
2 loading member
3 loading roller pins
4 specimen (II or III)
5 precrack
6 supporting roller pins
7 support member

b) Four-point bend test fixture

Dimensions in millimetres

Bending mode	**Specimen**	**Diameters of roller pins**	d_1 **(lower span)**	d_2 **(upper span)**
3-point bend	I	4,0 to 5,0	16 ± 0,2	–
3-point bend	II	4,0 to 5,0	30 ± 0,3	–
4-point bend	II	4,0 to 5,0	30 ± 0,3	10 ± 0,2
4-point bend	III	4,0 to 5,0	40 ± 0,4	20 ± 0,2

Figure 2 — Bend test fixtures

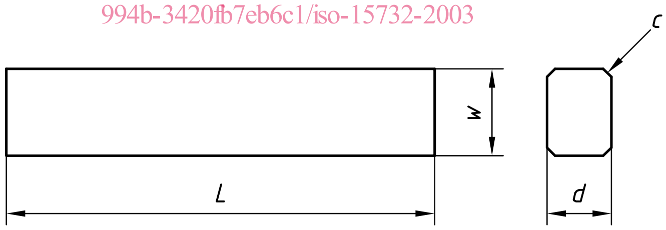
7 Test specimens

7.1 Shape and dimensions of specimen, and chamfering of edge

The shape of the specimens shall be that of a rectangular beam and its dimensions shall be as shown in Figure 3. Sampling position and orientation of specimen removal from raw material shall be recorded.

The opposing faces of the specimen shall be parallel to each other and the faces shall intersect perpendicularly. The maximum variation in parallelism and perpendicularity shall not exceed 0,01 mm as defined in ISO 1101.

Further, the four long edges of each specimen shall be chamfered uniformly at 45° ± 5°.The chamfered edge length shall be 0,12 mm ± 0,03 mm, as shown in Figure 3 (hereafter, a specimen of 18 mm or more in length is referred to as "specimen I", a specimen of 36 mm or more in length, as "specimen II", and a specimen of 45 mm or more in length, as "specimen III").



Dimensions in millimetres

Specimen	**Total length,** L	**Width,** w	**Thickness,** d	**Chamfering,** C
I	⩾ 18	4 ± 0,1	3 ± 0,1	0,12 ± 0,03
II	⩾ 36	4 ± 0,1	3 ± 0,1	0,12 ± 0,03
III	⩾ 45	4 ± 0,1	3 ± 0,1	0,12 ± 0,03

Figure 3 — Dimensions of specimen

7.2 Surface roughness of upper and lower surfaces and both side surfaces of specimen

The surface roughness of the four surfaces of the specimen, Ra, as defined in ISO 4287 excluding both end surfaces in the length direction shall be not more than 0,2 µm.