SLOVENSKI STANDARD
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Metode za preskušanje gostih oblikovanih ognjevzdržnih izdelkov - 7. del: Ugotavljanje upogibne trdnosti pri visokih temperaturah

Methods of test for dense shaped refractory products - Part 7: Determination of modulus of rupture at elevated temperatures

Prüfverfahren für dichte geformte feuerfeste Erzeugnisse - Teil 7: Bestimmung der Biegefestigkeit bei erhöhten Temperaturen

Méthodes d'essai pour produits réfractaires façonnés denses - Partie 7: Détermination du module de rupture a températures élevées

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This European Standard was approved by CEN on 4 September 1998.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 187 "Refractory products and materials", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 1999, and conflicting national standards shall be withdrawn at the latest by March 1999.

It is closely based on the corresponding International Standard, ISO 5013 'Shaped refractory products - Determination of modulus of rupture at elevated temperatures', published by the International Organization for Standardization (ISO).

Reproducibility and repeatability data are not available at present but can be included in a subsequent edition.

EN 993 "Methods of test for dense shaped refractory products" consists of 18 Parts:

Part 1 :	Determination of bulk density, apparent porosity and true porosity
Part 2 :	Determination of true density
Part 3 :	Test methods for carbon-containing refractories
Part 4 :	Determination of permeability to gases
Part 5 :	Determination of cold crushing strength
Part 6 :	Determination of modulus of rupture at ambient temperatures
Part 7 :	Determination of modulus of rupture at elevated temperatures
Part 8 :	Determination of refractoriness-under-load
Part 9 :	Determination of creep in compression
Part 10 :	Determination of permanent change in dimensions on heating
Part 11 :	Determination of resistance to thermal shock (ENV)
Part 12 :	Determination of pyrometric cone equivalent (refractoriness)
Part 13 :	Specification for pyrometric reference cones for laboratory use
Part 14	Determination of thermal conductivity by the hot-wire (cross-array) method
Part 15 :	Determination of thermal conductivity by the hot-wire (parallel) method
Part 16 :	Determination of resistance to sulphuric acid
Part 17 :	Determination of bulk density of granular materials by the mercury method with vacuum
Part 18 :	Determination of bulk density of granular materials by the water method with vacuum
Part 19 :	Determination of resistance to thermal expansion
Part 20 :	Determination of resistance to abrasion at ambient temperature

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies a method for the determination of the modulus of rupture of dense and insulating shaped refractory products at elevated temperatures, under conditions of a constant rate of increase of stress. A method for determination of the same property at ambient temperature is given in EN 993-6.

NOTE: The method relates primarily to fired refractories. If it is to be applied to chemically bonded or tar-bonded bricks (see EN 993-3 for guidance), the bricks will usually require some form of preliminary heat treatment. This preliminary treatment should be agreed between the interested parties and should be stated in the test report.

2 Normative references

This European Standard incorporates by dated or undated references, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 993-3 Methods of test for dense shaped refractory products - Part 3: Test methods for carbon - containing refractories

EN 993-6 Methods of test for dense shaped refractory products - Part 6: Determination of modulus of rupture at ambient temperature

EN 60584-1 Thermocouples - Part 1: Reference tables (IEC 60584-1:1995)

3 Definitions

For the purposes of this standard, the following definitions apply:

3.1 modulus of rupture: The maximum transverse stress that a prismatic test piece of specified dimensions can withstand when it is bent in a three-point loading device.

3.2 test temperature: The temperature at the mid-point of the tensile face of the test piece (see 5.3).

4 Principle

Test pieces taken from items (bricks) are heated to the test temperature. After being maintained at this temperature until a specified temperature distribution is reached, the test pieces are loaded at a constant rate of increase of tensile stress until failure occurs.

5 Apparatus

5.1 Loading device

5.1.1 The loading device shall have two bearing edges to support the test piece and one for the application of the load. The three bearing edges shall be parallel to each other. For normal test pieces, the distance between the bearing edges supporting the test piece shall be 125 mm ± 2 mm, with proportionate separations for other test piece lengths (see 6.2). The load bearing edge shall be placed centrally between the two supporting bearing edges to an accuracy of ± 2 mm (see figure 1).

5.1.2 The bearing edges and test pieces shall be free from any reaction on contact at the test temperature.

5.1.3 The bearing edges shall have a length at least 5 mm greater than the breadth of the test pieces and a radius of curvature of 5 mm ± 1 mm. Since the bearing edges become flattened with use, they shall be examined periodically to ensure that their radii remain within these limits.

5.1.4 The distance between the two supporting bearing edges (see figure 1) shall be measured at room temperature to an accuracy of ± 0,5 mm.

NOTE: This value is taken into account in the calculation of the modulus of rupture.

5.1.5 The loading device shall be capable of applying a load uniformly across the centre of the test piece and of increasing it at a constant rate. Means shall be provided for recording or indicating the load at failure to an accuracy of ± 2 %.

5.2 Furnace

5.2.1 The furnace shall be one of the following types:

a) batch type, in which a number of test pieces is heated to the test temperature together and tested in turn;

b) sequential type, in which the test pieces are heated to the test temperature one after another as they pass through the apparatus.

5.2.2 In either case, the furnace shall be capable of providing the temperature control and the overall heating of both the loading device and the test pieces, as required by 7.1.

5.2.3 The atmosphere in the furnace shall be air or some other specified gas, as agreed between the parties concerned in the test.

5.3 Temperature measuring device

5.3.1 The temperature of a test piece shall be measured using a calibrated thermocouple located in the proximity of the midpoint of the tensile face of the test piece.

5.3.2 The difference between the temperature measured by the thermocouple and the temperature at the midpoint of the tensile face shall first be established and shall be checked periodically in accordance with the procedure given in annex A.

5.4 Drying oven

5.5 Callipers, capable of measuring to an accuracy of ± 0,1 mm for measuring the test piece dimensions

5.6 Thermocouple, in accordance with EN 60584-1

6 Test pieces

6.1 Number

The number of test pieces to be tested for each item (brick) at each test temperature shall be agreed between the interested parties and shall be the same for each item; it shall be stated in the test report.

6.2 Shape and size

6.2.1 Unless otherwise agreed, the test piece shall be a rectangular bar with a cross-section of 25 mm ± 1 mm x 25 mm ± 1 mm and a length of about 150 mm. The longitudinal faces of each test piece shall be parallel to each other within a tolerance of ± 0,5 mm and the sides of a cross-section of the test piece shall be parallel to each other within ± 0,2 mm. Care shall be taken to ensure that the test pieces have smooth surfaces and clean edges. If other sizes of test piece are to be used, the dimensions shall be altered in steps of 5 mm, with a minimum of 100 mm for the length and a minimum of 10 mm for the width and for the height.

NOTE : The formula given in 8 is only valid for test pieces that are of a slender shape. It is therefore recommended that the ratio of the height (h) and width (b) of the test piece and the ratio of the height of the test piece to the distance between the supports (Ls) should be the following:

$$\frac{h}{L_s} < \frac{1}{4} \quad and \quad \frac{h}{b} > \frac{1}{3}$$

These are empirical values that have resulted from a study of several publications describing the influence of the dimensions of the test piece on the determination of the modulus of rupture.

6.2.2 The width and height of the cold test piece shall be measured at its midpoint with an accuracy of ± 0,1 mm.

NOTE: These values are taken into account in the calculation of the modulus of rupture.

6.3 Preparation

6.3.1 If the direction in which the brick was pressed is known, each test piece shall be cut out of the brick in such a way that the upper longitudinal face in the testing position (the face in compression) coincides with or was parallel to one of the original faces of the brick perpendicular to the direction of pressing. No other longitudinal face of a test piece shall include the original skin of the brick.

NOTE: Cutting with a continuous rim diamond wheel is recommended. If a wheel with a serrated rim is used, the edges of the cut where the wheel emerges are often frayed. It is therefore recommended that in such a case, the wheel should enter the face of the brick that is to form the tensile faces of the test pieces during the test.

6.3.2 The direction of pressing, if known, shall be marked on each test piece

6.3.3 The test pieces shall be dried at 110 °C ± 5 °C to constant mass

7 Procedure

7.1 Heating

7.1.1 The test temperature shall be as agreed between the interested parties. It is recommended that multiples of 100 °C should be used (e.g. 1 000 °C, 1 100 °C, ...), but if necessary multiples of 50 °C may be used.

7.1.2 Heat the test pieces to the test temperature ± 10 °C with a mean rate of heating between 2 °C/min and 10 °C/min and preferably between 4 °C/min and 6 °C/min.

7.1.3 When the test temperature is reached, maintain the test piece at this temperature for sufficient time for the temperature distribution in it to become uniform within ± 10 °C. The time allowed for this shall be stated in the test report.

NOTE : About 15 min to 30 min is usually sufficient for normal test pieces of fired bricks. For unfired bricks, a pre-treatment or soaking time and temperature should be agreed between the interested parties.

7.1.4 The temperature measured by the thermocouple near the midpoint of the tensile face of the test piece shall not vary during the time of testing by more than ± 2 °C.

7.2 Loading

7.2.1 Place a test piece on the lower bearing edges so that it rests symmetrically across them. If a longitudinal face of a test piece coincides with an original face of the brick, that face shall be the face in compression (see 6.3.1).

7.2.2 The rate of increase of the load shall be chosen so that the breaking time (from the commencement of a loading) is not less than 10 s. If a specimen fails in less than 10 s, the test shall be repeated, unless failure has already occurred at a rate of increase of 0,02 MPa/s. The retest shall be at a lower rate of increase of the load.

7.2.3 Apply the load vertically with a constant rate of increase, until failure occurs. The rate of increase of the load shall be calculated, using the formula given in clause 8, at one of the following rates of increase of tensile stress in the test piece, subject to 7.2.2:

a) for dense product of normal strength: 0,15 MPa/s ± 10 %;
b) for a dense product of low strength or an insulating refractory product of normal strength; 0,05 MPa/s ± 10 %;
c) for an insulating product of low strength 0,02 MPa/s ± 10 %.