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Refractory products — Determination of compressive strength at elevated temperature

Produits réfractaires — Détermination de la résistance à la compression à température élevée

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Foreword

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This document was prepared by Technical Committee ISO/TC 33, *Refractories.*

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.

Refractory products — Determination of compressive strength at elevated temperature

1 Scope

This document specifies a test method for determining the compressive strength of refractory products at elevated temperature.

This test method could also be used for materials development, quality control, characterization, design and data generation purposes.

NOTE This document also could be used for determining the compressive strength of carbon containing refractory products at elevated temperature in an airtight furnace with reducing atmosphere.

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 5022, *Shaped refractory products — Sampling and acceptance testing*

ISO 1927-2, *Monolithic (unshaped) refractory products — Part 2: Sampling for testing*

ISO 1927-5, *Monolithic (unshaped) refractory products — Part 5: Preparation and treatment of test pieces*

ISO 8895, *Shaped insulating refractory products — Determination of cold crushing strength*

ISO 10059-1, *Dense, shaped refractory products — Determination of cold compressive strength — Part 1: Referee test without packing*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
compressive strength at elevated temperature
maximum load (applied under specified conditions at elevated temperature) divided by the area over which the load is applied, that a refractory will withstand before failure occurs

4 Principle

A test piece of known dimension is subjected, at test temperature and under specified conditions, to an increasing compressive load until failure occurs (fracture occurs, or strain reaches 1 % for dense refractory products or 10 % for shaped insulating refractory products, respectively). The compressive strength at elevated temperature is calculated from the maximum load that a refractory will withstand before failure occurs and the mean cross-sectional area over which the load is applied.

NOTE The unit of compressive strength at elevated temperature is N/mm^2 (MPa).

5 Apparatus

5.1 Furnace

5.1.1 The furnace shall be able to heat the test piece to the setting temperature with a constant heating rate. The temperature deviation shall be less than 20 °C while the test temperature is above 500 °C.

5.1.2 The hot end of the thermocouple should be located at the middle of the test piece. The distance between the test piece and the hot end of the thermocouple should be less than 10 mm.

The furnace design should be such that the test pieces and columns can be easily installed.

5.2 Loading device

5.2.1 General

The capacity of the test machine shall be greater than 10 % of the expected load at fracture or the maximum load before the strain reaches the expected value. The accuracy of the load measurement exerted on the test piece should be within 2 %. The test machine shall be capable of applying loads with a constant stress rate meeting the requirements of 7.4.1 for dense shaped refractory products or 7.4.2 for insulating refractory products and recording the load-strain curve.

5.2.2 Loading column

The loading column shall be a cylinder at least 60 mm in diameter, or a rectangular column at least 60 mm in side length. The loading column sits on a spherical seating material that will compensate for small deviations from parallelism between the columns and the test piece. The loading column shall be capable of withstanding the applied load up to the end of test.

5.2.3 Supporting column

The supporting column shall be a cylinder at least 60 mm in diameter, or a rectangular column at least 60 mm in side length. The supporting column shall be capable of withstanding the applied load up to the end of test.

5.2.4 Discs

a) The discs shall be placed between the columns and test piece to prevent a possible reaction between their components.

b) The discs shall be made of a suitable refractory material compatible with the material under test. (e.g. high-fired mullite or alumina for alumina-silicate products, and magnesia or spinel for magnesia products).

c) The discs shall be capable of withstanding the applied load up to the end of test.

d) The diameter or side length shall be about 5 mm longer than that of column and the thickness shall be approximately 30 mm to 50 mm.

5.3 Deformation measuring device

It shall be capable of measuring and recording the deformation of test pieces when loading. An appropriate measuring instrument, such as dial-gauge or a length transducer, could be used only if its sensitivity is better than 0,005 mm.

5.4 Calipers

The calipers shall be capable of measuring to at least 0,1 mm.

5.5 Electrical oven

The oven shall be capable of heating to 110 °C ± 5 °C.

5.6 Set square

5.7 Feeler gauge

6 Test pieces

6.1 Sampling

Sampling of shaped refractory products shall be in accordance with ISO 5022. A single test piece shall be taken from a standard brick, or a test item equal to or less than 2 000 cm^3, or two test pieces from shapes of significantly larger volume. The number of test items should be in accordance with an agreed sampling plan and noted in the test report. A minimum of three test pieces is recommended or shall be agreed between the parties concerned and noted in the test report. Sampling of unshaped refractory products shall be in accordance with ISO 1927-2.

6.2 Dimensions

The dimensions of test pieces shall be cylinders of 50 mm ± 0,5 mm in height and 50 mm ± 0,5 mm in diameter.

NOTE If it is not possible to prepare cylinders, cubes of 40 mm ± 0,5 mm in side length can be used as an alternative.

If the compressive strength of materials at elevated temperature is extremely high, cylinders with a height of less than 50 mm or cubes with side length of less than 40 mm could be used as test pieces. For insulating refractory products, cylinders shall only be used as test pieces.

The dimension shall be noted in the test report.

6.3 Preparation

6.3.1 Shaped refractory products

Test pieces shall be drilled or cut from the test items so that the load applied during testing is in the same direction as the forming pressure during manufacture, where this is known. The original position of the test pieces in the test items shall be noted. Test pieces containing cracks or obvious defects on any of the surfaces shall be discarded and this shall be noted in test report.

NOTE It is suggested to grind two loading surfaces of test piece with a double-head diamante flat grinder.

6.3.2 Dense unshaped refractory products

Three test pieces prepared at the same time shall be tested. The test pieces shall be prepared and stored according to the relevant clauses of ISO 1927-5. Cutting or drilling should be performed after drying at 110 °C/24 h to ensure enough mechanical strength. The test piece should then be dried again immediately. The direction of load-applying shall be perpendicular to the direction of fabrication except for the cylindrical test pieces.

For castables with high strength, cylindrical test pieces shall be prepared instead of cubic test pieces. The surface bearing load shall be ground to ensure that it is plane and parallel. For castables with low strength, cubic test pieces shall be prepared. For ramming materials, taphole and dry mixes, cylindrical test pieces can only be used.

6.4 Dimension checking

6.4.1 Plane of loading surfaces

Both ends of the cylindrical test piece shall be made plane and parallel, grinding the surfaces where required. To ensure that the top and bottom ends of the test pieces are plane over their surface, each end shall in turn be pressed, with a load of 3 kN ± 1 kN, onto a levelling plate which is lined with carbon or blue paper and hard filter paper (0,15 mm in thickness) according to ISO 10059-1. Test pieces that do not show two complete, clearly visible coloured impressions shall be reground.

6.4.2 Parallelism of loading surfaces

The parallelism of the test pieces shall be checked by four measurements of the height at the extremities of two perpendicular diameters for a cylinder, or for a cube, along four edges between the load-bearing faces. The difference between any two of these measurements shall not exceed 0,2 mm.

6.4.3 Perpendicularity

The perpendicularity shall be checked by placing the test piece on a plane surface and using a set square placed against the sides of the test piece at four positions corresponding to the height measurements. The gap between the side of the test piece and the set square shall be not more than 0,5 mm when measured with the feeler gauges.

6.5 Drying and treatments

The prepared test pieces shall be carefully dried to constant mass by placing them in a drying oven at 110 °C ± 5 °C for 24 h. They are then cooled to room temperature and stored in a low moisture atmosphere until the start of the test. If necessary, pre-treatment for dense unshaped refractory products shall be performed according to ISO 1927-5.

For unfired test pieces, the test shall be carried out immediately after drying and cooling. For fired test pieces, the test shall be carried out within three days after drying and cooling.

7 Procedures

7.1 Dimension measurement

7.1.1 Diameter

a) For cylindrical test pieces, measure two perpendicular diameters of each load-bearing surface to within 0,1 mm using the calipers. From the arithmetic mean of these four measurements, calculate the initial cross-sectional area, A_0.

b) For cubic test pieces, measure two perpendicular medians of each load-bearing surface to within 0,1 mm using the calipers. From the arithmetic mean of these four measurements, calculate the initial cross-sectional area, A_0.

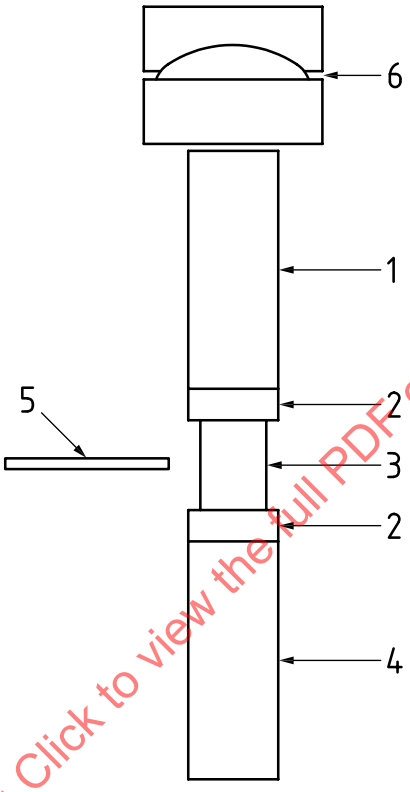
7.1.2 Height

a) For cylindrical test pieces, measure four heights at the extremities of two perpendicular diameters to within 0,1 mm using the calipers. From the arithmetic mean of these four measurements, calculate the average height, h_0.

b) For cubic test pieces, the direction of measurement shall be along the loading. Measure four heights in the middle of edges to 0,1 mm using the calipers. From the arithmetic mean of these four measurements, calculate the average height, h_0.

7.2 Installation

7.2.1 Install the test piece according to Figure 1.



Key

1 loading column
2 disc
3 test piece
4 supporting column
5 thermocouple
6 spherical seating

Figure 1 — Location of test piece with discs, columns and thermocouple

7.2.2 Check the thermocouple, load cell, displacement transducer and ensure the load, temperature and strain can be continuously recorded.

7.3 Heating

7.3.1 Test temperature

The test temperature shall be set according to defined product requirements or agreed between interested parties.