BRITISH STANDARD

BS EN
13161:2008

Natural stone test methods — Determination of flexural strength under constant moment

ICS 73.020; 91.100.15

National foreword

This British Standard is the UK implementation of EN 13161:2008. It supersedes BS EN 13161:2001 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/545, Natural stone.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

Natural stone test methods - Determination of flexural strength under constant moment

Méthodes d'essai pour pierres naturelles - Détermination de la résistance en flexion sous moment constant

Prüfverfahren für Naturstein - Bestimmung der Biegefestigkeit unter Drittellinienlast

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Contents

Page

Foreword

This document (EN 13161:2008) has been prepared by Technical Committee CEN/TC 246 “Natural stones”, the secretariat of which is held by UNI.

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of an identical text or by endorsement, at the latest by October 2008, and conflicting national standards shall be withdrawn at the latest by October 2008.

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This document supersedes EN 13161:2001.

This European Standard is one of the series of European Standards for tests on natural stone.

Test methods for natural stone consist of the following parts:

EN 1925, *Natural stone test methods — Determination of water absorption coefficient by capillarity*

EN 1926, *Natural stone test methods — Determination of uniaxial compressive strength*

EN 1936, *Natural stone test methods — Determination of real density and apparent density and of total porosity and open porosity*

EN 12370, *Natural stone test methods — Determination of resistance to salt crystallisation*

EN 12371, *Natural stone test methods — Determination of frost resistance*

EN 12372, *Natural stone test methods — Determination of flexural strength under concentrated load*

EN 12407, *Natural stone test methods — Petrographic examination*

EN 13364, *Natural stone test methods — Determination of the breaking load at dowel hole*

EN 13373, *Natural stone test methods — Determination of geometric characteristics on units*

EN 13755, *Natural stone test methods — Determination of water absorption at atmospheric pressure*

EN 13919, *Natural stone test methods — Determination of resistance to ageing by SO_2 action in the presence of humidity*

EN 14066, *Natural stone test methods — Determination of resistance to ageing by thermal shock*

EN 14146, *Natural stone test methods — Determination of the dynamic modulus of elasticity (by measuring the fundamental resonance frequency)*

EN 14147, *Natural stone test methods — Determination of resistance to ageing by salt mist*

EN 14157, *Natural stone test methods — Determination of abrasion resistance*

EN 14158, *Natural stone test methods — Determination of rupture energy*

EN 14205, *Natural stone test methods — Determination of Knoop hardness*

EN 14231, *Natural stone test methods — Determination of the slip resistance by means of the pendulum tester*

EN 14579, *Natural stone test methods — Determination of sound speed propagation*

EN 14580, *Natural stone test methods — Determination of static elastic modulus*

EN 14581, *Natural stone test methods — Determination of linear thermal expansion coefficient*

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1 Scope

This European Standard specifies a method to determine the flexural strength of natural stones under constant moment. This European Standard contains provision for both an identification test and for a technological test.

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.

EN 12390-4, *Testing hardened concrete — Part 4: Compressive strength — Specification for testing machines*

EN 12390-5, *Testing hardened concrete — Part 5: Flexural strength of test specimens*

3 Principle

After appropriate preparation a specimen of the rock to be tested is laid and centred between two supports. Thereafter the specimen is subjected to a load using two parallel rollers acting on the top surface of the specimen. These loading rollers are centred and located a distance of one third of the length of span. The loads are steadily increased until failure.

4 Symbols

R_{tc} flexural strength at constant moment, in Megapascals;

F load at failure in Newtons;

b specimen width in millimetres;

h specimen thickness in millimetres;

L specimen length in millimetres;

ℓ distance between the supporting rollers, in millimetres.

5 Apparatus

5.1 A **balance capable** of weighing the specimen with a reading up to 0,01 % of the mass to be weighed.

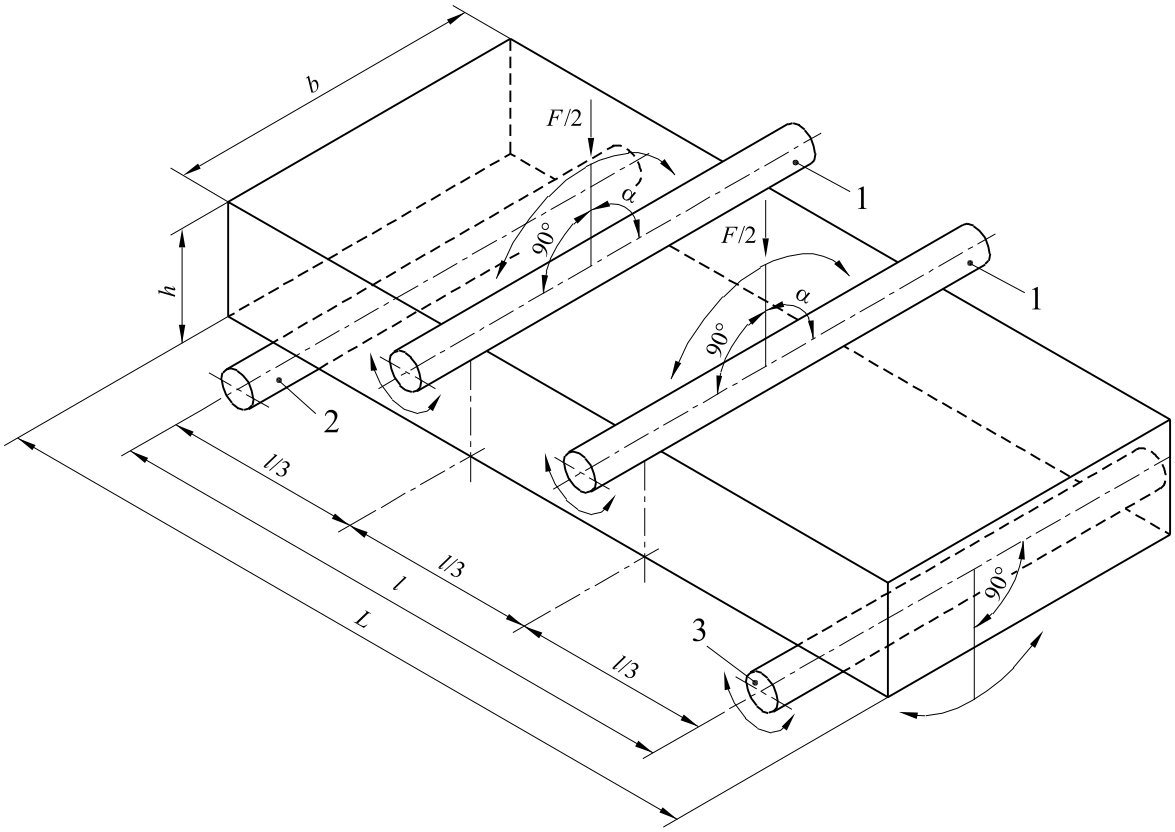
5.2 A **ventilated oven** capable of maintaining a temperature of (70 ± 5) °C.

5.3 A **linear measuring device** with a reading up to 0,05 mm.

5.4 A **test machine** of appropriate force, in accordance with EN 12390-4 and calibrated according to this European Standard.

5.5 A **device** for applying loads on the specimen by a two-points load, in accordance with EN 12390-5. It consists of two upper rollers (load-applying rollers) and two lower rollers (supporting rollers): see Figure 1. The distance between the two supporting rollers shall be reported as requested in 6.2.2.

5.6 A **room** which can be maintained at a temperature of (20 ± 10) °C.



Key

1 load applying rollers

2, 3 supporting rollers

Figure 1 — Arrangement of loading of a test specimen (two point loading)

6 Preparation of specimens

6.1 Sampling

The sampling is not the responsibility of the testing laboratory except when it is especially requested. At least 10 specimens shall be selected from a homogeneous batch (see also 6.2.4).

6.2 Test specimens

6.2.1 Surface finish

As a standard reference, the surface finish of the faces of the specimens shall be sawn, honed or polished (identification test). When it is necessary to carry out the test on final products (technological test) the surface finish of the specimens may be flamed, sandblasted etc., depending on the final use. For the technological test the specimens may be final products or sawn from final products. The surface intended for use shall be in

contact with the two supporting rollers (facing downwards). However the kind of surface finish shall be stated in the report.

6.2.2 Dimensions

The dimensions of the specimens are determined by their thickness *h*:

— the thickness *h* shall be between 25 mm and 100 mm and shall be greater than twice the size of the largest crystal in the stone;

— the total length *L* shall be equal to six times the thickness;

— the distance between the supporting rollers ℓ shall be equal to five times the thickness;

— the width *b* shall be between 50 mm and three times the thickness (50 mm ≤ b ≤ 3*h*), and in no case it shall be less than the thickness.

6.2.3 Limit deviations

The limit deviation on the dimensions *h*, *b*, *L* and ℓ shall be ± 1 mm of the nominal dimensions.

In the case of identification test the faces shall not depart from perpendicularity to the axis of the specimen by more than 2 % with a maximum of 2 mm difference, when measured in any direction.

6.2.4 Planes of anisotropy

6.2.4.1 Identification test

If the stone shows planes of anisotropy (e.g. bedding, foliation), the direction of the planes of anisotropy is to be marked on each specimen by at least two parallel lines.

If the use of the stone in respect of the position of the planes of anisotropy is known, the test shall be carried out with the force applied to the face that will be loaded during use.

If the way of use of the stone is not known but the position of the planes of anisotropy is indicated on the specimens, the test shall be carried out on each of the three arrangements shown in Figures from 2 to 4; the total number of specimens will then be 3 times 10.

6.2.4.2 Technological test

The specimens shall be tested only for the relevant product direction that is, with the force applied to the face which will be loaded during use.

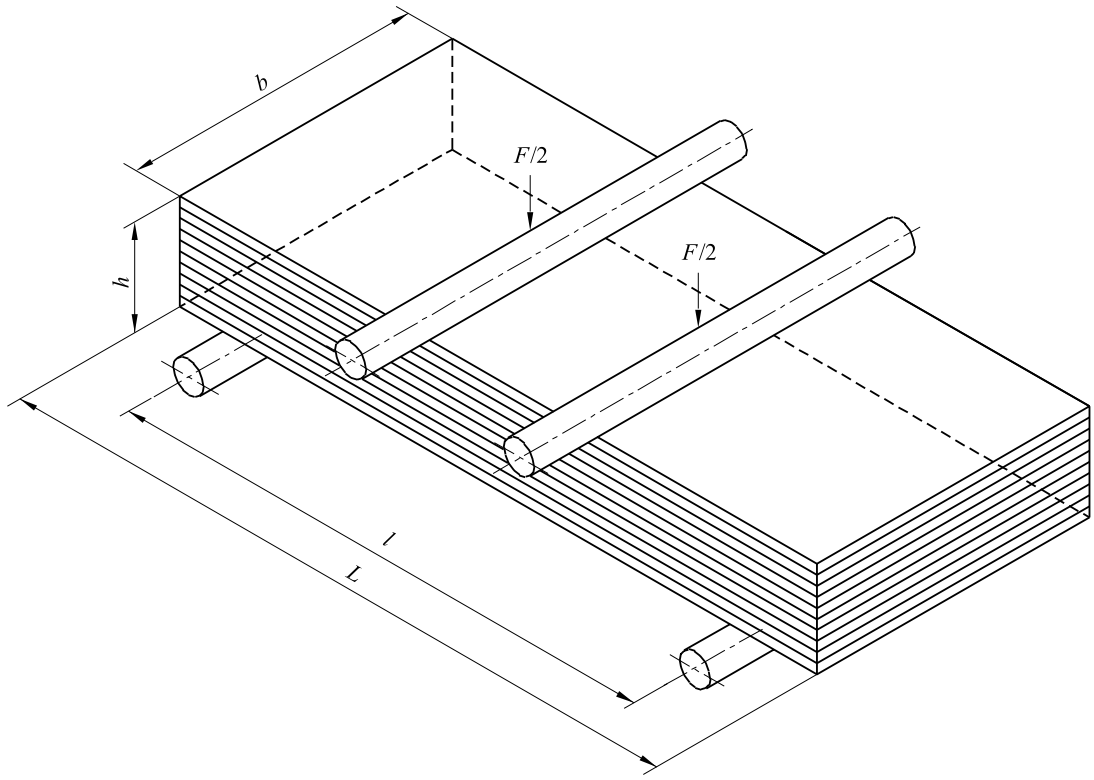


Figure 2 — Test arrangement for a specimen with the load applied perpendicular to the planes of anisotropy

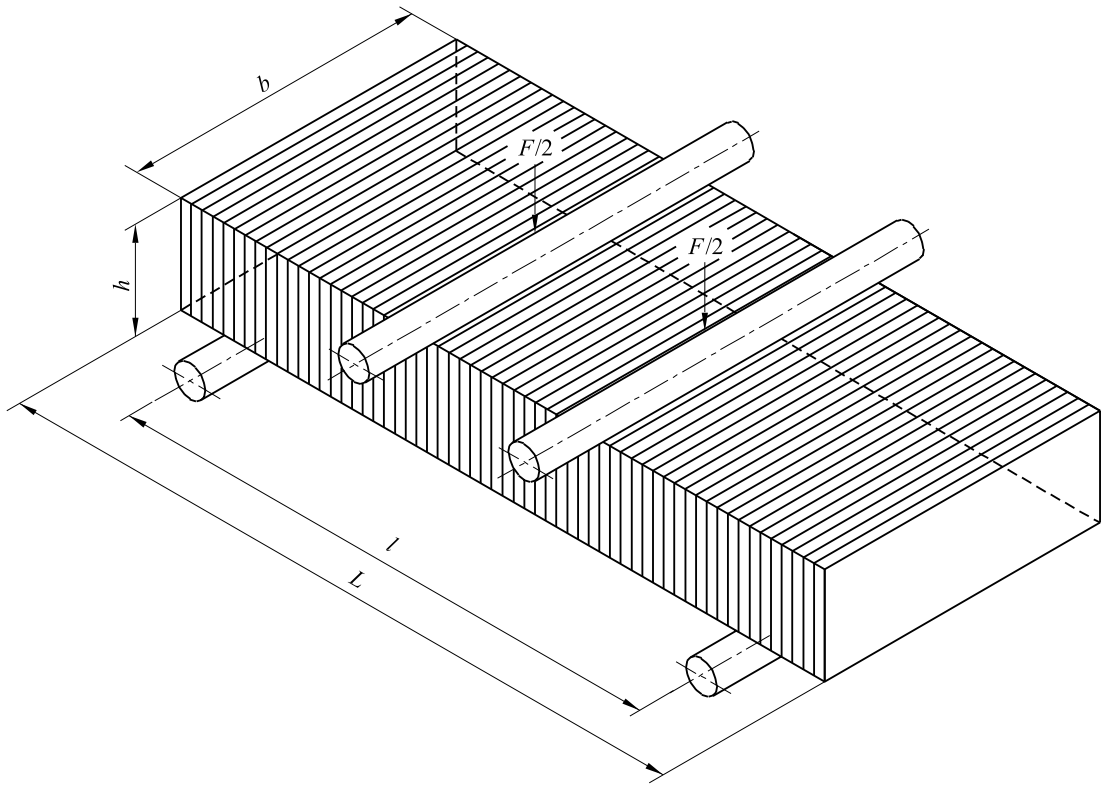


Figure 3 — Test arrangement for a specimen with the load applied parallel to the planes of anisotropy

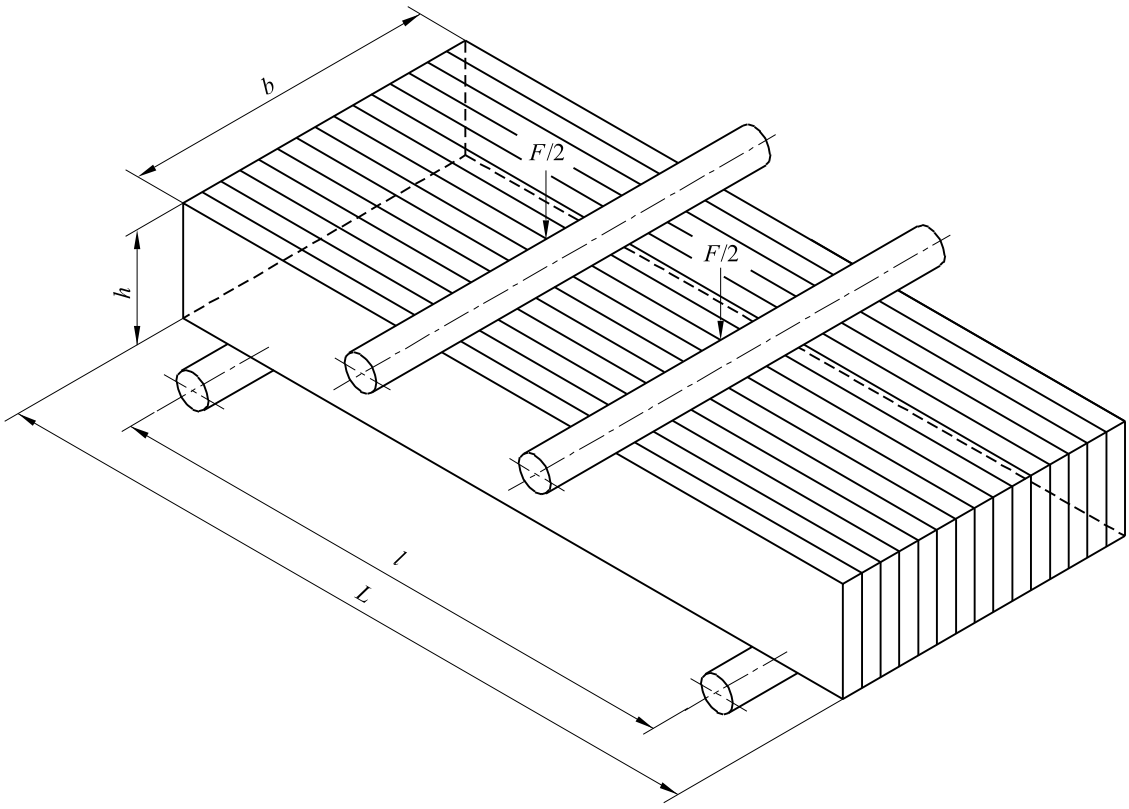


Figure 4 — Test arrangement for a specimen with the load applied perpendicular to the edges of the planes of anisotropy

6.2.5 Conditioning before testing

The specimens shall be dried at (70 ± 5) °C to constant mass. Constant mass shall be considered to have been reached when the difference between two weighings made at an interval of (24 ± 2) h is not greater than 0,1 % of the previous mass measurement.

After drying and before testing the specimens shall be stored at (20 ± 10) °C for thermal equilibrium to be reached, and the test shall be performed within 24 h after removal from the oven.

7 Test procedure

Wipe the surfaces of the rollers clean and remove any loose grits from the faces of the specimen which will be in contact with the rollers. Align the specimen carefully and centrally between the supports and the loading cylinders such to gain uniform setting as shown in Figure 1. Specimen position regarding anisotropy directions is visualized in Figures 2, 3 and 4.

The load is increased uniformly at a rate equivalent to (0,25 ± 0,05) MPa/s until failure.

The maximum load on the specimens shall be recorded to the nearest 10 N and the place and mode of the fracture shall be recorded if the failure has occurred outside the two line loads.

NOTE Where the loading rate (V, in N/s) is needed, the following equation can be used to determine the required rate:

$$V = \frac{2abh^2}{3l} \text{ (N/s)}$$

8 Expression of results

For each specimen the flexural strength at constant moment R_{tc} is calculated by the Equation (1):

$$R_{tc} = \frac{F \times l}{b \times h^2} \quad (1)$$

The result shall be expressed in Megapascals to the nearest 0,1 MPa.

9 Test report

The test report shall contain the following information:

a) unique identification number of the report;

b) the name, number, and date of issue of this European Standard, i.e. EN 13161:2008;

c) the name and address of the test laboratory and the address where the test was carried out if different from the testing laboratory;

d) the name and the address of the client;

e) it is the responsibility of the client to supply the following information:

- the petrographic name of the stone;
- the commercial name of the stone;
- the country and region of extraction;
- the name of the supplier;
- the direction of any existing plane of anisotropy (if relevant to the test) to be clearly indicated on the sample or on each specimen by means of two parallel lines;
- the name of the person or organization which carried out the sampling;

f) the date of delivery of the sample or of the specimens;

g) the date when the specimens were prepared (if relevant) and the date of testing;

h) the number of specimens in the sample;

i) the surface finish of the specimens;

j) the perpendicularity to the axis of the specimens;

k) for each specimen:

- width (b) and thickness (h) to the nearest 0,1 mm;

— length (L) and the length of span (ℓ) to the nearest 1 mm;

— failure load to the nearest 10 N;

— flexural strength (R_{tc}) in MPa to the nearest 0,1 MPa;

— loading direction in relation to any anisotropy;

— mode and place of the fracture when outside the two line loads;

l) for each relevant direction of loading the mean value $\overline{R}_{tc}$ of the flexural strength and the standard deviations, in Megapascals to the nearest 0,1 MPa;

m) any deviation from this standard and the reason for such deviation;

n) remarks.

The test report shall contain the signature(s) and role(s) of the responsible(s) for the testing and the date of issue of the report.

It shall also state that the report shall not be partially reproduced without the written consent of the laboratory.

Annex A
(normative)

Statistical evaluation of the test results

A.1 Scope

This annex establishes a method for the statistical treatment of test results obtained following the natural stone test method described in this standard.

A.2 Symbols and definitions

Measured values	$x_1, x_2, .. x_i .., x_n$
Number of measured values	n
Mean value	$\bar{x} = \frac{1}{n}\sum_i x_i$
Standard deviation	$s = \pm\sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$
Coefficient of variation	v = $\frac{s}{\bar{x}}$ (for individual values)
Logarithmic mean	$\bar{x}_{\ln} = \frac{1}{n}\sum_i \ln x_i$
Logarithmic Standard deviation	$s_{\ln} = \pm\sqrt{\frac{\sum (\ln x_i - \bar{x}_{\ln})^2}{n-1}}$
Maximum value	Max.
Minimum value	Min.
Lower expected value	$E = e^{\bar{x}_{\ln} - k_s \cdot s_{\ln}}$ where ks (quantile factor) is given in Table A.1
Quantile factor	k_s see Table A.1

A.3 Statistical evaluation of test results

For the calculation of the mean value $(\bar{x})$, the standard deviation (s) and the coefficient of variation (v) a normal distribution is assumed.

For the calculation of the lower expected value (E) a logarithmic normal distribution is assumed. The lower expected value (E) corresponds to the 5 % quantile of a logarithmic normal distribution for a confidence level of 75 %.

Table A.1 — Quantile factor (k_s) in dependence on the number of measured values (n) in correspondence to the 5 % quantile for a confidence level of 75 %

n	k_S
3	3,15
4	2,68
5	2,46
6	2,34
7	2,25
8	2,19
9	2,14
10	2,10
15	1,99
20	1,93
30	1,87
40	1,83
50	1,81
∞	1,64

The following examples should help to clarify the method:

EXAMPLE 1

Calculation of mean value, standard deviation, maximum value and minimum value of 6 measured values

Measurement no.	Measured value x
1	2 000
2	2 150
3	2 200
4	2 300
5	2 350
6	2 400

Mean value	2 333
Standard deviation	147
Maximum value	2 400
Minimum value	2 000

EXAMPLE 2

Calculation of mean value, standard deviation, coefficient of variation and lower expected value of 10 measured values

Measurement no.	Measured value x	(ln x)
1	2 000	(7,60)
2	2 150	(7,67)
3	2 200	(7,70)
4	2 300	(7,74)
5	2 350	(7,76)
6	2 400	(7,78)
7	2 600	(7,86)
8	2 750	(7,92)
9	2 900	(7,97)
10	3 150	(8,06)
	---	---
Mean value	2 480	(7,807)
Standard deviation	363	(0,143)
Variation coefficient	0,15	

From Table A.1 for: n=10 k_S=2,1

lower expected value 1 819

Bibliography

[1] EN 12440, *Natural stone — Denomination criteria*

[2] EN 12670, *Natural stone — Terminology*

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