BS EN 16306:2013

BSI Standards Publication

Natural stone test methods — Determination of resistance of marble to thermal and moisture cycles

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 16306:2013.

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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2013

ISBN 978 0 580 75405 0

ICS 73.020; 91.100.15

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 28 February 2013.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 16306

February 2013

ICS 73.020; 91.100.15

English Version

Natural stone test methods - Determination of resistance of marble to thermal and moisture cycles

Méthodes d'essai pour pierres naturelles - Détermination de la résistance du marbre aux cycles thermiques et d'humidité

Prüfverfahren für Naturstein - Bestimmungen der Beständigkeit von Marmor bei zyklischer Belastung mit Wärme und Feuchtigkeit

This European Standard was approved by CEN on 7 December 2012.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

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 CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

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

Management Centre: Avenue Marnix 17, B-1000 Brussels

Contents

Page

Foreword

This document (EN 16306:2013) 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 August 2013, and conflicting national standards shall be withdrawn at the latest by August 2013.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard specifies a laboratory method for determining the resistance to thermal and moisture cycling of marble intended for cladding of building facades.

For scientific definition of marble, reference is made to EN 12670:2001, Terminology: 2.1.243 a.

NOTE Bowing and rapid strength loss is known to occur in some marbles when used as exterior claddings.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

EN 12670:2001, *Natural stone – Terminology*

EN 13161, *Natural stone test methods – Determination of flexural strength under constant moment*

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

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

EN ISO 4892-1:2000, *Plastics - Methods of exposure to laboratory light sources - Part 1: General guidance (ISO 4892-1:1999)*

3 Terms and definitions

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

3.1
bowing
change in shape from flat and planar to a curved or dished shape in a convex or concave direction

Note 1 to entry: Other terms commonly used for the same phenomenon are dishing and warping. Convex bowing is quantified by positive values, concave bowing by negative values.

3.2
convex
centre part of the specimen is bowing upwards, away from the moist substratum

3.3
concave
centre part of the specimen is bowing downwards, against the moist substratum

4 Principle

Bowing is measured on test samples exposed to moisture from beneath and heating from above. The temperature interval is from 20°C to 80°C, one cycle completed each 24 h. The 80 ºC is measured on a black reference, placed on the surface of one specimen to control the climate of the chamber/bath.

The potential strength loss is measured according to EN 12372 or EN 13161 on reference and exposed specimens (Annex A).

5 Symbols

T temperature

H_0 initial height of the specimen at the measuring point [mm]

H difference between the initial height and the height after a given cycle [mm]

H_N the normalised height difference, related to L_N = 1 m [mm]

B H_N / L_N = the normalised bowing value [mm/m]

B_n bow values after n cycles [mm/m]

L distance between the supports under the specimen = 0,35 [m]

L_N normalised length = 1 [m]

6 Apparatus

6.1 A non-corrosive bath (Figure 1) of sufficient capacity to hold the required number of specimens. The container must be designed in a way that specimens receive continuous moisture from one side and are exposed to cyclic heating on the other side. The container shall be furnished with a device that ensures a constant water level during the cycling. Lying on the bottom of the container is a grating, which is covered by a sheet of heat stable filter cloth.

6.2 A non-corrosive grating that fits the length and width of the container and has a height of at least 1 cm. The function of the grating is to ensure a water reservoir beneath the filter cloth.

6.3 A soft, heat and dimension stable non-hygroscopic needle filter cloth of thickness approximately 5 mm and without any water soluble substances or chemicals. The cloth (e.g. polyester or PTFE (polytetrafluoroethylene) needle felt) is to be placed on top of the grating. The function of the cloth is to provide moisture and a uniform support to the specimen.

6.4 Heating panels of sufficient sizes/and numbers to cover the container. The panels must be capable of providing a uniform heat flow, heating the black reference from 20 °C to 80 °C at average rate of (0,30 ± 0,05) °C per minute. The maximum allowed temperature difference within the bath, during heating exposure, is 3 °C. Walls of insulating material should preferably be placed around the container (Figure 1) to avoid unwanted cooling or air circulation. Before the system is taken into use, trial measurements of the temperature shall be performed at nine surface points widely distributed within the heating frame (Figure 2). The temperature is measured on a uniform surface preferably with an infrared thermometer or a surface measuring thermometer. The temperature readings shall be taken on the surface of the black reference.

NOTE 1 The heating rate may be adjusted by changing the distance between the heating device and the samples, or by controlling the effect of the heater. The heating curve is displayed in Figure 5.

6.5 A black reference plate, according to EN ISO 4892-1:2000 (Figure 3), to establish the maximum surface temperature at 80°C. The black reference is connected by a thermocouple (cable type K), preferably to a high stability temperature and process controllers. A simple logger is also possible.

NOTE 2 The black reference is placed on the surface of the measured sample, preferably in the middle of the container. The temperature for the experimental exposure is programmed in advance. The heating elements are connected to the whole system and are controlled by the process controller. The temperature of the black reference is

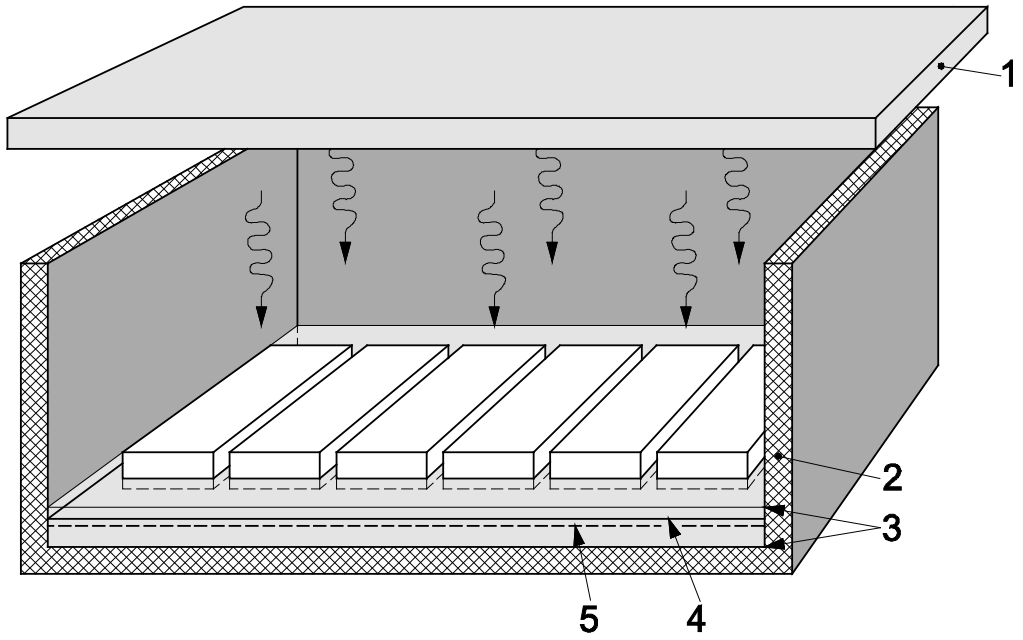
read and the signal is sent to the process controller that adjusts the heating. The whole system can thus be computer-controlled and the surface temperature can be monitored on-line.

6.6 An infrared thermometer or other thermometer capable of measuring the surface temperature of the specimens.

6.7 A bow-test rig for bow measurements (Figure 4). The rig is composed of a steel plate with three supporting points upon which the specimen is lying, and three cylinders guiding the edges of the specimen. The supporting points are situated (350 ± 5) mm apart from each other, and they must be well rounded and smooth in order to accommodate for eventual irregularities in the sawn surface of the specimens. Above the centre of the specimen a gauge is mounted, which shall be readable to 0,001 mm. The whole system shall have an accuracy better than ± 0,01 mm.

6.8 A reference cylinder (coplanar bases with an accuracy better than ± 0,005 mm) consisting of a material with a low linear expansion coefficient (e.g. quartz glass or invar steel).

6.9 A ventilated oven capable of maintaining a temperature of (40 ± 5)°C.



Key

1 heating device
2 insulation
3 water level
4 filter cloth
5 grating

NOTE The front wall is omitted here for a better view of the interior.

Figure 1 — Principle sketch and an example of exposure equipment for testing the potential bowing properties of marble

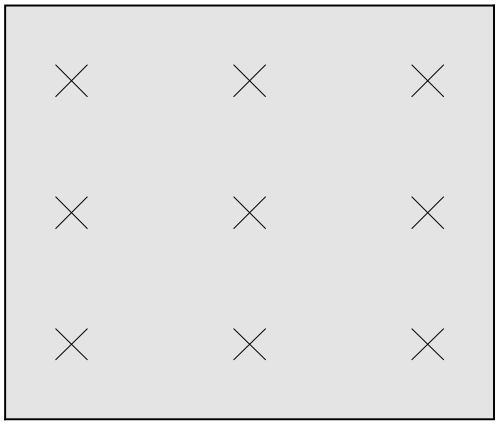
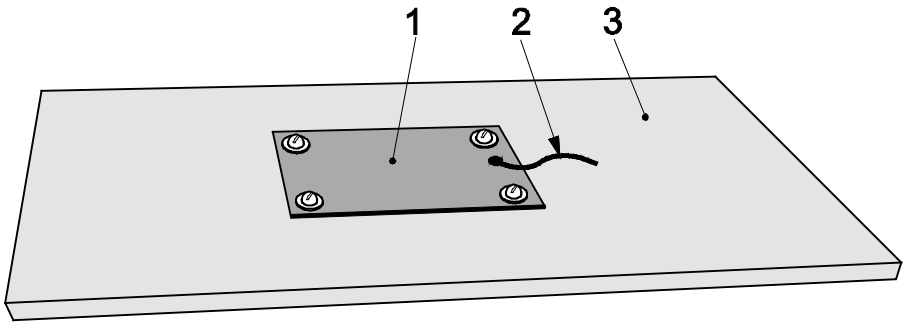


Figure 2 — Location of temperature control points

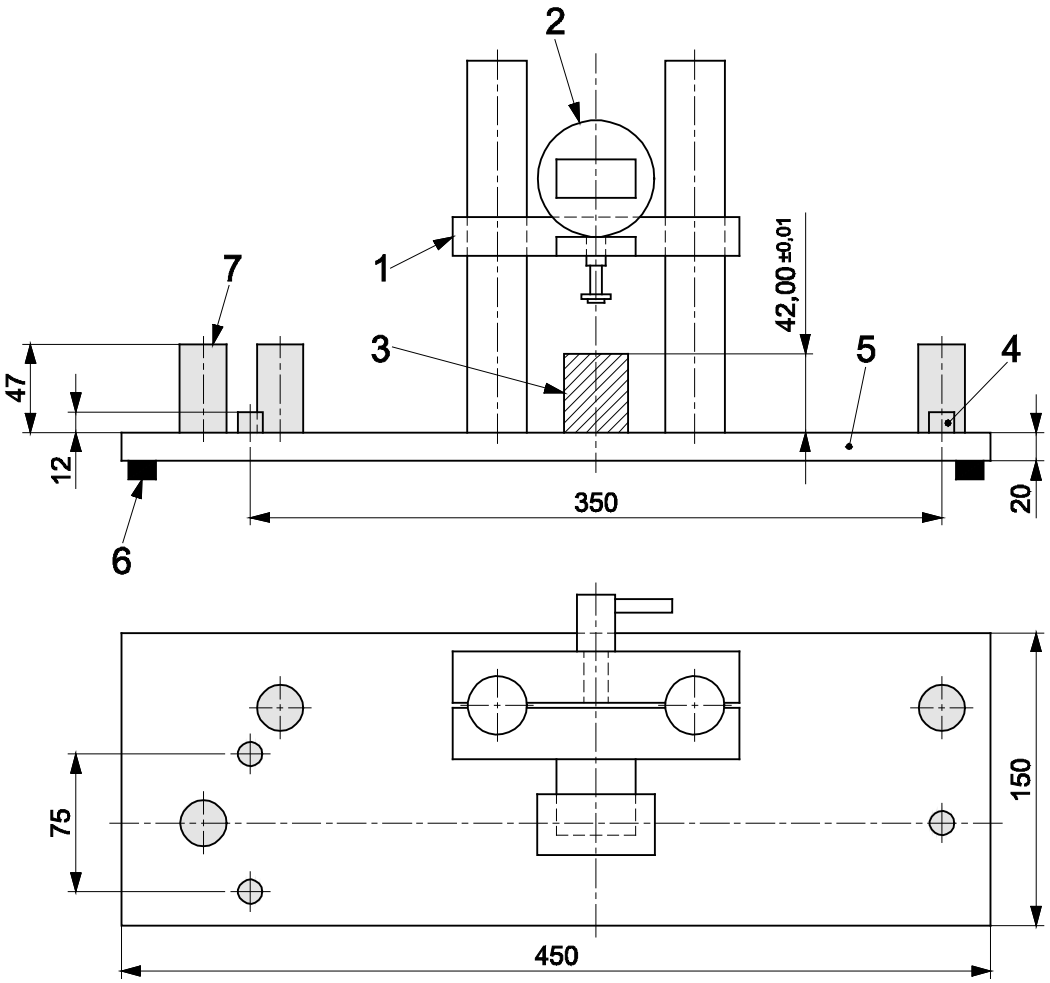


Key

1 black reference
2 thermocouple
3 test specimen

Figure 3 — Black reference plate (EN ISO 4892-1:2000) for T-measurements

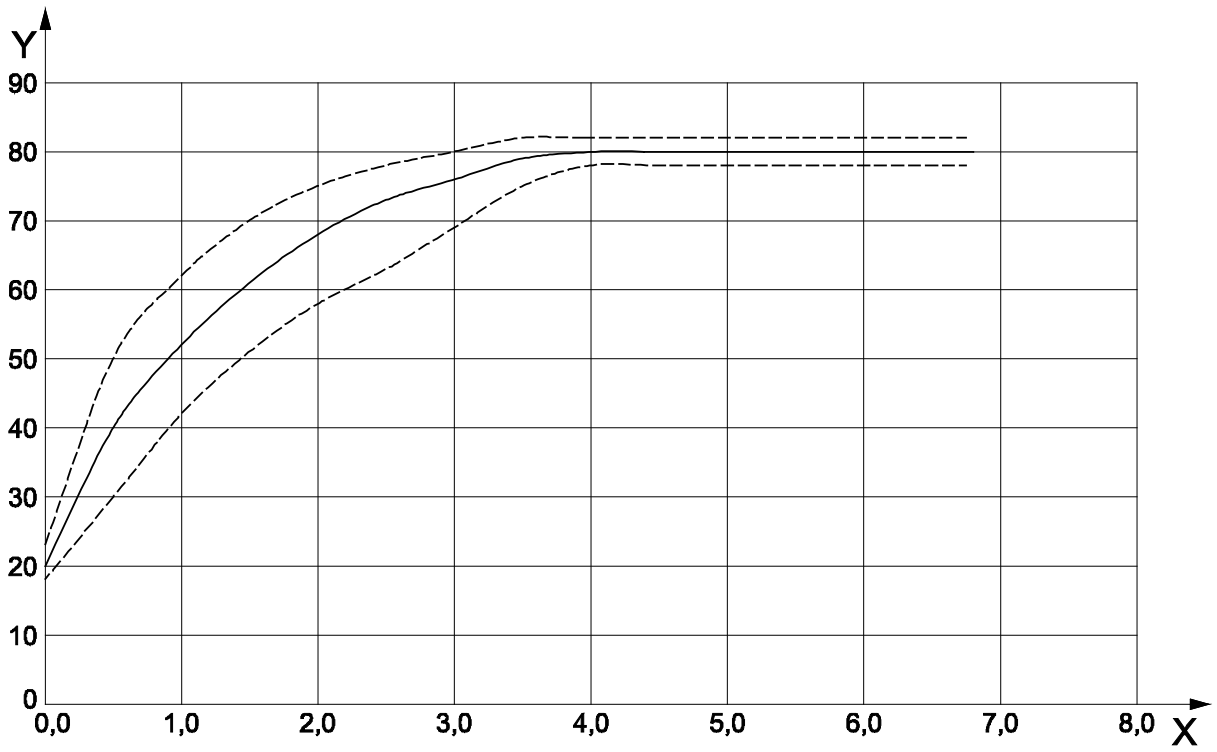
Dimensions in millimetres



Key

1 stand
2 gauge
3 reference piece
4 support
5 steel plate (rust resistance)
6 rubber studs
7 guide

Figure 4 — Schematic drawing of the bow test rig



Key

X time (h)
Y temperature, black ref. (°C)

_____ ideal temperature curve
– – – – – – upper and lower tolerances

Figure 5 — Requested temperature cycle and allowed tolerance

7 Preparation of specimens

7.1 Sampling

The sampling is not the responsibility of the test laboratory except where specifically requested.

At least six specimens are to be exposed and another set of six specimens are to be used as references for flexural strength measurement of unexposed material. Samples shall be chosen in order to be representative of the batch to be tested. For identification testing, any foliation must be taken into consideration. Six specimens with faces perpendicular to and six specimens parallel to the foliation must be selected. For technological tests, it is sufficient to select samples with one set of orientations according to the use of the slabs.

NOTE For very heterogeneous marble types, it has proven valuable to double the number of test specimens.

7.2 Test specimens

Test specimens shall be slabs with a length of (400 ± 5) mm, a width of (100 ± 5) mm and a thickness of (30 ± 2) mm. The upper surfaces of the specimen shall be honed (not polished) and the back surface shall be smooth. The specimens must not be chemically treated in any way.

7.3 Reference marks on the specimens

To ensure that successive bow measurements are carried out on the same measuring spot and on the same surface and oriented specimens, make indelible marks on the specimens. Number the specimens in consecutive order.

7.4 Drying the specimen

The specimens are dried in a ventilated oven at (40 ± 5) °C for one week and then cooled to ambient temperature (20 ± 5) °C before the start of the exposure.

8 Test procedure

8.1 Control measurements before cycling

After drying and cooling, a reference (H_0) height measurement is carried out at the point of the bow measurement.

8.2 Procedure for bow measurement

Each specimen is gently placed on the three supporting points touching each of the three guide cylinders. The specimen must be placed exactly in the same manner at each measurement. The pin of the gauge is gently lowered to the surface of the specimen and the reading is made. Essential to the measurement is also that the specimens, supporters, guides and gauge pin are clean. Water and dust must be removed from the contact points before measuring of each test specimen.

The test is sensitive and the specimens must be handled very carefully. When the specimen is lifted, it is done so by carefully holding at each end of the slab. Never put anything on the specimen or apply any kind of pressure to it since it will affect the result. The reference piece (cylinder, see 6.8 and Figure 4) is also measured before and after each test set measurement for zero setting.

8.3 Readings, exposure and duration of test

After the control measurement (8.1), place the specimens partly immersed in demineralised or distilled water for 24 h. Only the lower (5 ± 2) mm of the specimens are to be submerged while the top 25 mm shall remain above water level. The water level shall remain constant during all cycles. If necessary, make sure to top up with water of the same temperature as in the test bath. The specimens are placed on the filter cloth in the container, which is filled with demineralised or distilled water so that the specimens are partly immersed in the same way as described above. The specimens are exposed to a temperature cycle, heating the surface of the black reference from 20 °C to 80 °C in 3h-4h. The rate should not exceed 0,35 °C per minute and the maximum temperature is maintained for between 1 and 3 h (Figure 5). The heater is then turned off and the specimen cool down to ambient temperature (20 ± 5) °C. No control of the cooling phase is necessary, other than making sure that ambient temperature has been reached before measuring the bow of the specimens. (22 ± 2) h after the cycle started (approximately 1h to 2h before starting the next T-cycle) the bow of the specimen is measured, by taking out the specimens one by one from the container, i.e. the specimens that are not measured shall remain in the container, in contact with the water. Rearrange the specimens in the container before the next cycles. The heating-cooling cycle is repeated 50 times. Bow measurements are made after each of the first five cycles and thereafter at every fifth cycle.

NOTE Before the specimens are exposed to heating cycles, another height measurement may be taken. This value is only used for comparative measurements during the cycling.

8.4 Measurements after exposure

After the last cycle, and any wet measurement, the exposed specimens and the reference specimens shall be dried for one week at (40 ± 5) °C, cooled down to ambient temperature and measured for permanent bow.

This measurement is used as the final measurement and shall be compared with the initial measurement in a dry state (H_0).

During drying, the specimens shall stand upright on the long edge and with a distance to each other to allow for circulating air between.

9 Calculation of results

9.1 Bowing magnitude

After each bow measurement the magnitude of the bowing is given by the difference in "height" ΔH to the first reading (H_0). This normalised bow measure (H_N) is calculated as the height difference, in mm, for a specimen with the length of 1 [m] yielding the unit [mm/m].

$$H_N = \Delta H \cdot \left(\frac{L_N}{L} \right) \quad (1)$$

where

H_N is the normalised height difference

ΔH is the measured height difference

L_N is the normalisation length (1 m)

L is the distance between the supports under the specimens (0,35 m).

The formula is also valid with different distance between the supports. Only insert the corresponding value of L). Finally, the bowing is given as:

$B = H_N / L_N$ (2)

It is recommended to present results in both a diagram and a table. The mean values of the six specimens shall be calculated with their standard deviations. The bowing values after cycle number 5, 10, 25 and 50 should be reported in tables.

Diagrams showing all bow values as a function of numbers of cycles are also recommended.

9.2 Flexural strength

Measure the flexural strength on dried reference and on dried exposed specimens. The percentage change in flexural strength (ΔF) is calculated as follows:

$$\Delta \mathrm{Rtf} = \frac{\mathrm{R}_{\mathrm{tfn}} - \mathrm{R}_{\mathrm{tfr}}}{\mathrm{R}_{\mathrm{tfr}}} \cdot 100 \quad (3)$$

where

R_{tfn} is the flexural strength of exposed specimens

R_{tfr} is the flexural strength of reference specimens

ΔR_{tf} % is the change in flexural strength, expressed as a percentage

10 Precision

Awaits data from precision trial.

11 Test report

The test report shall contain the following information:

a) the unique identification number of the report;

b) the number, title and date of issue of this European Standard;

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

d) the name and address of the client;

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

   1) the petrographic name of the stone;

   2) the commercial name of the stone;

   3) the country and region of extraction;

   4) the name of the supplier;

   5) the direction of any existing plane of anisotropy to be clearly indicated on the samples or on each specimen by means of two parallel lines;

   6) the name of the person or organisation, which carried out the sampling;

   7) the surface finish of the specimens;

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 dimensions of the specimens;

j) the number of cycles;

k) the individual values of bowing, the mean value and the corresponding graph and table;

l) the individual values of flexural strength, the mean value, the standard deviation and the percentage difference between the mean value obtained on references specimens and the mean value obtained on exposed specimens;

m) all deviations from the standard and their justification;

n) remarks.

The test report shall contain the signature(s) and role(s) of the person(s) responsible for the testing and the date of issue of the report. It shall also state that the report shall not be partially reproduced without written consent of the test laboratory.

Annex A
(informative)

Guidance on limit values

A.1 General

The following criteria should be fulfilled for a marble to be considered for outdoor cladding:

— the permanent bowing should be less than 0,40 mm/m after 50 cycles;

— the increase rate in bowing should not exceed 0,02 mm/m in the last two measurements.

A.2 Flexural strength

The flexural strength values of reference specimens and exposed specimens provide important information about the potential strength loss that may occur during the service life of the marble panels.

For a marble evaluated as suitable in the bow test, the flexural strength, after the test should be used for dimensioning of façade panels.

Annex B
(informative)

Non-destructive testing

B.1 General

Ultrasonic Pulse Velocity, UPV (EN 14579) and dynamic modulus of elasticity (EN 14146) may be used as non-destructive tests to monitor internal changes (micro-fissuring) in the marble during the test.

In such cases, these parameters shall be measured before the test has been initiated on the dried samples and after the 50th cycle has been completed and the test specimens dried. Mark the positions where the transducers and responders are used with indelible marks.

NOTE The UPV can also be used on site and correlated with strength measurements for non-destructive in situ investigations and prediction of remaining service life when tested recurrently.

B.2 Ultrasonic velocity

The ultrasonic pulse velocity of the specimens is measured according to EN 14579. The transducer points shall be placed close to the edges of the specimens for indirect measurements, see EN 14579, Annex A. This is to be regarded as the initial value (V_0).The ultrasonic pulse velocity is measured on dried reference and exposed specimens. The percentage change in ultrasonic velocity (ΔV) is calculated as follows:

$$\Delta V\,\% = \frac{V_0 - V_n}{V_0} \cdot 100 \qquad \text{(B.1)}$$

where

V_0 is the ultrasound pulse velocity of reference specimens, in km/s

V_n is the ultrasound pulse velocity of exposed specimens in km/s

ΔV % is the change in ultrasound pulse velocity expressed as a percentage

B.3 Modulus of elasticity

The resonance frequency of each specimen is measured according to EN 14146 and the modulus of elasticity subsequently calculated. The value shall be regarded as the initial (E_0).

The resonance frequency is measured on dried reference (E_0) and exposed specimens (E_f). Calculate the change in dynamic elastic modulus to the nearest 0,1 % according to the formula:

$$\Delta E\,\% = \frac{E_0 - E_f}{E_0} \cdot 100 \qquad \text{(B.2)}$$

where

E_0 is the dynamic elastic modulus of reference specimens, in MPa

E_f is the dynamic elastic modulus of exposed specimens, in MPa

ΔE % is the change in dynamic elastic modulus expressed as a percentage

Annex C
(informative)

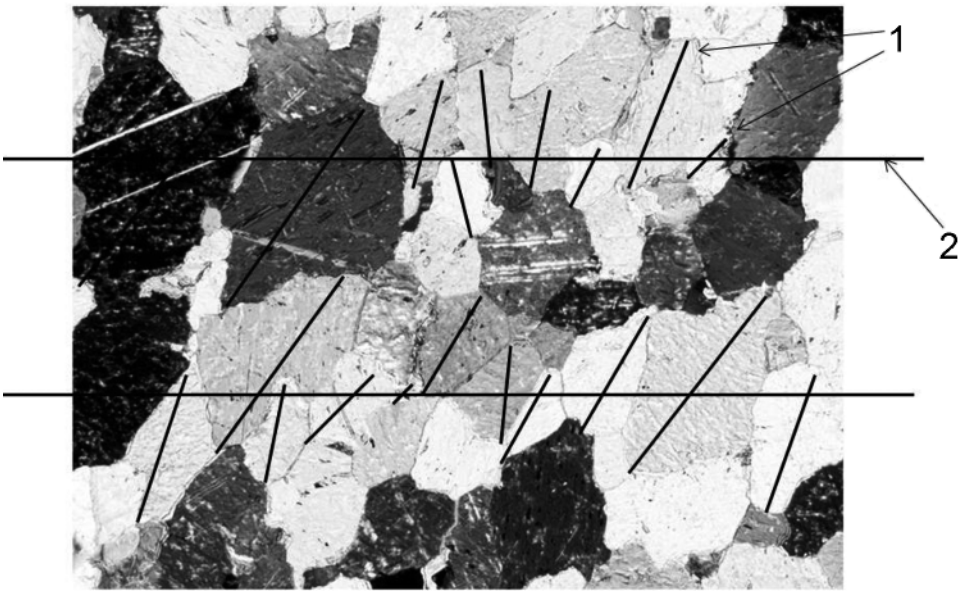
Enhanced petrographic analysis

C.1 General

This guidance serves as an enhancement of EN 12407, *Natural stone test methods – Petrographic examination*. The procedure described below can be carried out completely manually, by printing photos on paper and measuring thereon, or by computer-aided image analysis. The main objective of the method is to get a quick impression of the microstructure and the marble's potential suitability for exterior use. It can also be used for production control of blocks selected for a specific building project and quality mapping of a quarry.

The microstructure of marble is a reflection of its geological history. This also defines whether the marble will be durable in outdoor applications. A more complex microstructure is favourable. A requirement should be based on a quantitative parameter/measure and not a subjective measure. This quantitative, analysis procedure, called the Adjacent Grain Analysis (AGA), is valid for calcitic marble. Calcite belongs to the hexagonal crystal system. A marble with ideal granoblastic polygonal microstructure has 6 AG (adjacent grains, see Figure C.2). A more complex structure yields a higher number of adjacent grains.

Initially, the grain size distribution shall be determined by the linear traverse method (see Figure C.1). The Feret diameter (longest axis of each grain) is measured along the traverses. At least 100 grains should be measured. The spacing of the traverses depends on the grain size, i.e. the traverses shall be spread as in a standard point-counting of minerals. The value of the median grain size is used. At least 50 median sized grains are chosen and the number of adjacent grains (AG) around each one of them is counted (see Figure C.2). The median value of all counts represents the AGA result. An AGA of 8 or higher is good. 7 is an intermediate value while 6 is too low (see Figure C.3).



Key

1 feret diameter
2 traverse

Figure C.1 — Linear traverse method for determination of the grain size distribution

NOTE 1 It is not only the grain contacts but also the grain size distribution that influences the durability. A wide range of grain sizes is favourable for the durability.

NOTE 2 The principle of a complex microstructure is also valid for dolomitic marble types. However, there is no satisfactory correlation between the AGA and the bowing potential, or rapid strength loss. On the other hand, dolomitic marble more seldom have problems with rapid deterioration.

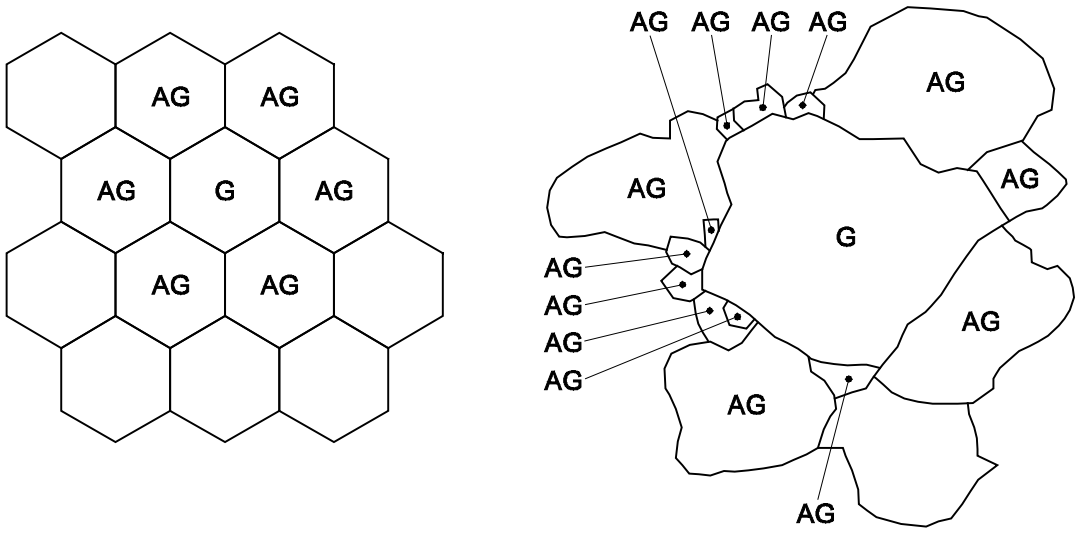


Figure C.2 — Principle for counting the number of adjacent grains (AG) around median sized grains (G). Ideal granoblastic structure to the left and a more seriate, interlobate structure to the right

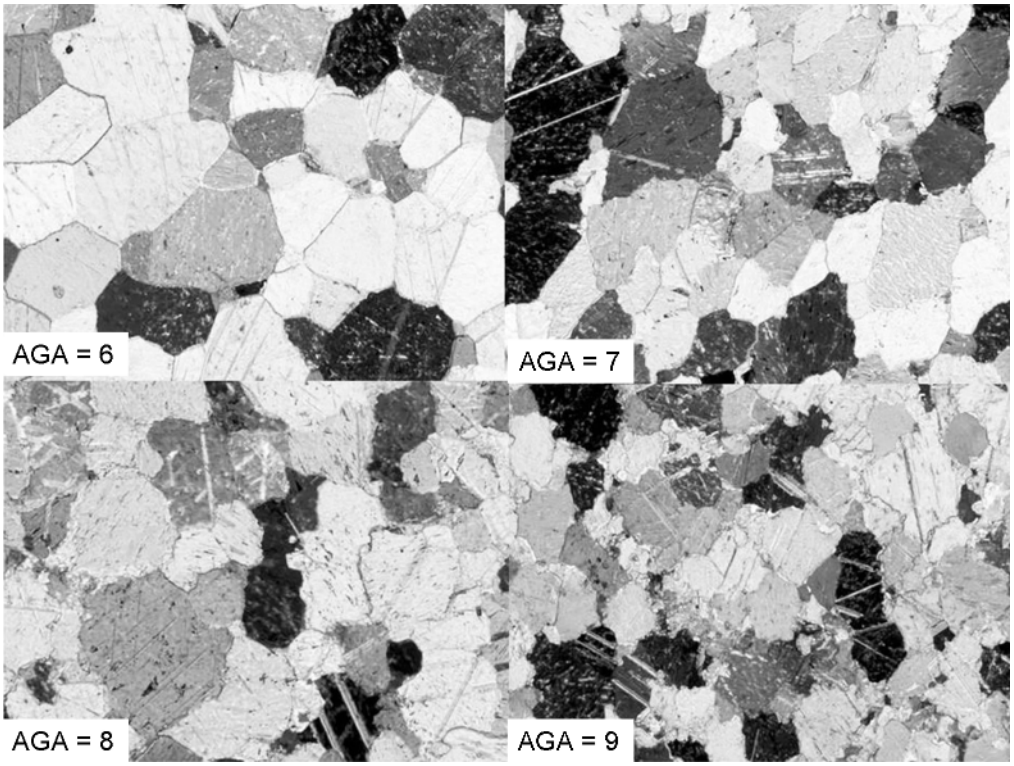


Figure C.3 — Example of four different calcitic marble types with AGA from 6 to 9. The performance of these marble types is verified from buildings

Bibliography

[1] EN 12407, *Natural stone test methods – Petrographic examination*

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

bsi.

...making excellence a habit.™