

BS 8298-5:2023



BSI Standards Publication

Design and installation of natural stone cladding and lining

Part 5: Internal cladding and lining – Code of practice

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Summary of pages

This document comprises a front cover, an inside front cover, pages I to IV, pages 1 to 78, an inside back cover and a back cover.

Foreword

Publishing information

This part of [BS 8298](#) is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 June 2023. It was prepared by Technical Committee B/545, *Natural stone*. A list of organizations represented on this committee can be obtained on request to the committee manager.

Supersession

This part of [BS 8298](#) supersedes [BS 8298:1994](#) and partially supersedes [BS 8298-1:2010](#), which are withdrawn.

Relationship with other publications

[BS 8298](#) is published in the following parts:

- Part 2: *Traditional handset external cladding – Code of practice*;
- Part 3: *Stone-faced pre-cast concrete cladding systems – Code of practice*;
- Part 4: *Stone cladding on rainscreen support systems – Code of practice*; and
- Part 5: *Traditional handset internal cladding – Code of practice*.

Information about this document

To provide more consistency with other material design standards, it is the long-term goal for the partial safety factors presented in the British Standard to be derived from a reliability-based analysis in accordance with the principles of BS EN 1990:2020+A1:2005, Annex D. However, the values presented in this edition are derived from industry experience and a historical precedent of conformity and not a reliability-based analysis.

This publication can be withdrawn, revised, partially superseded or superseded. Information regarding the status of this publication can be found in the Standards Catalogue on the BSI website at bsigroup.com/standards, or by contacting the Customer Services team.

Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Use of this document

As a code of practice, this part of [BS 8298](#) takes the form of guidance and recommendations. It is not to be quoted as if it were a specification. Users are expected to ensure that claims of compliance are not misleading.

It has been assumed in the preparation of this part of [BS 8298](#) that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Users may substitute any of the recommendations in this part of [BS 8298](#) with practices of equivalent or better outcome. Any user claiming compliance with this part of [BS 8298](#) is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word “should” is used to express recommendations of this standard. The word “may” is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word “can” is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. “organization” rather than “organisation”).

Contractual and legal considerations

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1 Scope

This part of [BS 8298](#) gives recommendations for the design, installation and maintenance of internal cladding and lining of natural stone held directly to a structural background by fixings with or without adhesive. It is applicable for both commercial and residential locations.

It covers four categories of construction build up:

- a) internal cladding ≥ 20 mm thick, with a cavity, supported at each floor level, mechanically supported and restrained;
- b) internal lining ≤ 2.4 m height, ≥ 20 mm thick (e.g. ≥ 600 mm $\times$ 600 mm to 2 400 mm $\times$ 600 mm) supported at floor level, stack-bonded, on adhesive, mechanically restrained to the substrate;
- c) internal lining ≤ 2.4 m height, ≥ 12 mm to ≤ 20 mm (e.g. ≤ 600 mm $\times$ 600 mm), supported at floor level, stack-bonded, on adhesive, mechanically restrained to the substrate; and
- d) ceilings, soffits and sloping surfaces with a cavity mechanically supported and restrained.

Stone held only by adhesion is not included.

It covers:

- 1) the sampling of stone for testing and production control testing (PCT);
- 2) the provisions necessary for cladding and lining to perform their function satisfactorily; and
- 3) the materials and methods most frequently used for stonework.

This document is not applicable to seismic loading or enhanced security scenarios (such as blast).

NOTE Different cladding methods are covered in the other parts of [BS 8298](#) (see Foreword).

This standard excludes composite stone slabs, such as honeycomb-backed stone, and open internal courtyards.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions, or limits the application, of this document¹⁾. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[BS 5234-1](#), *Partitions (including matching linings) – Part 1: Code of practice for design and installation*

[BS 5385-4](#), *Wall and floor tiling – Part 4: Design and installation of ceramic and mosaic tiling in specific conditions – Code of practice*

[BS 5606](#), *Accuracy and tolerance in design and construction – Guide*

[BS 6093](#), *Design of joints and jointing in building construction – Guide*

[BS 6100-6](#), *Building and civil engineering – Vocabulary – Part 6: Construction parts*

[BS 6180](#), *Barriers in and about buildings – Code of practice*

[BS 8539](#), *Code of practice for the selection and installation of post-installed anchors in concrete and masonry*

[BS EN 197-1](#), *Cement – Part 1: Composition, specifications and conformity criteria for common cements*

[BS EN 413-1](#), *Masonry cement – Part 1: Composition, specifications and conformity criteria*

¹⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

- [BS EN 459-1](#), *Building lime – Part 1: Definitions, specifications and conformity criteria*
- [BS EN 934-3](#), *Admixtures for concrete, mortar and grout – Part 3: Admixtures for masonry mortar – Definitions, requirements, conformity and marking and labelling*
- [BS EN 1469:2015](#), *Natural stone products – Slabs for lining – Requirements*
- [BS EN 1926](#), *Natural stone test methods – Determination of uniaxial compressive strength*
- [BS EN 1936](#), *Natural stone test methods – Determination of real density and apparent density, and of total and open porosity*
- [BS EN 1990:2002+A1:2005](#), *Eurocode – Basis of structural design*
- [BS EN 1991-1-1](#), *Eurocode 1: Actions on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings*
- [BS EN 1991-1-4](#), *Eurocode 1: Actions on structures – Part 1-4: General actions – Wind actions*
- [BS EN 1992-4](#), *Eurocode 2: Design of concrete structures – Part 4: Design of fastenings for use in concrete*
- [BS EN 1993-1-4](#), *Eurocode 3: Design of steel structures – Part 1-4: General rules – Supplementary rules for stainless steels*
- [BS EN 10088-2](#), *Stainless steels – Part 2: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes*
- [BS EN 10088-3](#), *Stainless steels – Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes*
- [BS EN 12004-1](#), *Adhesives for ceramic tiles – Part 1: Requirements, assessment and verification of constancy of performance, classification and marking*
- [BS EN 12370](#), *Natural stone test methods – Determination of salt crystallization*
- [BS EN 12372](#), *Natural stone test methods – Determination of flexural strength under concentrated load*
- [BS EN 12407](#), *Natural stone test methods – Petrographic examination*
- [BS EN 12440](#), *Natural stone – Denomination criteria*
- [BS EN 12670](#), *Natural stone – Terminology*
- [BS EN 12878](#), *Pigments for the colouring of building materials based on cement and/or lime – Specifications and methods of test*
- [BS EN 13139](#), *Aggregates for mortar*
- [BS EN 13161](#), *Natural stone test methods – Determination of flexural strength under constant moment*
- [BS EN 13364](#), *Natural stone test methods – Determination of the breaking load at dowel hole*
- [BS EN 13373](#), *Natural stone test methods – Determination of geometric characteristics on units*
- [BS EN 13755](#), *Natural stone test methods – Determination of water absorption at atmospheric pressure*
- [BS EN 14066](#), *Natural stone test methods – Determination of resistance to ageing by thermal shock*
- [BS EN 15651-3](#), *Sealants for non-structural use in joints in buildings and pedestrian walkways – Part 3: Sealants for sanitary joints*
- [BS EN 16140](#), *Natural stone test methods – Determination of sensitivity to changes in appearance produced by thermal cycles*
- [BS EN 16301](#), *Natural stone test methods – Determination of sensitivity to accidental staining*

[BS EN 16306](#), *Natural stone test methods – Determination of resistance of marble to thermal and moisture cycles*

[BS ISO 6707-1](#), *Building and civil engineering works – Vocabulary – Part 1: General terms*

NA to BS EN 1991-1-1, *UK National Annex to Eurocode 1: Actions on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings*

NA to BS EN 1991-1-4, *UK National Annex to Eurocode 1: Actions on structures – Part 1-4: General actions – Wind actions*

Other publications

[N1] CENTRE FOR WINDOW AND CLADDING TECHNOLOGY. *Technical Note 75: Impact performance of building envelopes: Guidance on specifications*. Bath: CWCT, 2012.

[N2] CENTRE FOR WINDOW AND CLADDING TECHNOLOGY. *Technical Note 76: Impact performance of building envelopes: Method for impact testing cladding slabs*. Bath: CWCT, 2012.

3 Terms and definitions

For the purposes of this part of [BS 8298](#), the terms and definitions given in [BS ISO 6707-1](#), [BS 6100-6](#) and [BS EN 12670](#) and the following apply.

3.1 backer rod

material placed in a joint cavity behind the sealant to control the depth of sealant without inhibiting joint movement

3.2 backing structure

secondary frame to which stone is fixed, generally located between the primary structure and the stone

NOTE Secondary frame can include subframe and SFS.

3.3 backing wall

layer of the wall that provides airtightness and watertightness, and which can be used for fixing stone

NOTE The backing wall can be an integral part of the system or it can be part of the building to which cladding and lining are added.

3.4 bimetallic corrosion

corrosion caused by contact between dissimilar metals in the presence of an electrolyte, such as water

3.5 cavity barrier

construction within a cavity, other than a smoke curtain, to perform either of the following functions:

- close a cavity to stop smoke or flame entering; and
- restrict the movement of smoke or flame within a cavity

[SOURCE: *The Building Regulations 2010. Approved Document B* [1]]

3.6 characteristic value (f_k , F_k , R_k)

value of a material product property derived from testing, which can be either mean value or lower expected value (LEV)

NOTE See commentary on [5.5.5](#).

3.7 cladding or lining

internal covering to a structure

NOTE 1 Cladding is typically installed using mechanical fixings in an atria with a cavity. Lining is typically adhesively bonded without a cavity and mechanically fixed/restrained.

NOTE 2 Handset cladding or lining are stone slabs seated one upon another on a mortar bed, supported at defined levels on loadbearing angles and fixed directly to the structure, with each stone unit secured with restraint fixings.

3.8 design team

group of people with experience in cladding, lining and interfacing trades

NOTE A design team typically comprises an architect, interior designer, structural engineer and stone specialist.

3.9 design value (f_d , F_d , R_d)

value obtained by applying a partial factor γ_m or γ_f to a characteristic value

3.10 facing

layer of stone attached to a backing wall

3.11 fascia

plain vertical surface

NOTE A fascia is normally situated over an opening.

3.12 fire stop (fire stopping)

sealing or closing of an imperfection of fit between elements, components or construction of a building, or any joint, so as to restrict penetration of smoke and flame through the imperfection or joint

[SOURCE: BS 9999:2017, 3.52, modified]

3.13 fixings and anchors

3.13.1 anchor

retention device or element used to fix a stone slab or a dimensioned stone, usually to a wall, for cladding or lining

3.13.2 back anchor

anchor installed in a parallel hole (held with or without cement/resin)

NOTE The back anchor and parallel hole may be cranked.

3.13.3 combined loadbearing and restraint fixing

device that transfers the self-weight of one or more cladding or lining units to the structure and provides some restraint

3.13.4 dowel

metallic cylindrical bar used in conjunction with other fixing components, as distinct from a pin

3.13.5 expansion anchor

anchor that works by a process of mechanical expansion against the sides of the hole into which it is fixed

3.13.6 face fixing

fixing through the exposed face of the stone which combines the function of a loadbearing and/or restraint fixing

3.13.7 fastener

screw, bolt, rivet or other component used to secure two or more components together, typically as part of a framing or bracket system

3.13.8 fixing

combination of bracket and fasteners/anchors

3.13.9 hollow bolt

stainless steel expansion bolt for hollow steel sections

3.13.10 loadbearing fixing

fixing which is intended to support the weight (dead load) of the object being fixed, as well as any other applied (live) loads

3.13.11 pin

metallic cylindrical bar which is typically of a smaller diameter than a dowel and used to connect two stones in conjunction with an adhesive

3.13.12 restraint fixing

device to restrain or tie back cladding or slabs to the structure

NOTE The term “tying back fixing” is deprecated.

3.13.13 self-tapping screw

screw that taps its own hole

NOTE Also known as “self-drilling”.

3.13.14 soffit and ceiling fixing

device that carries both its own weight and restraint of a natural stone surface that varies from horizontal to 75°

3.13.15 steel frame system (SFS)

cold formed galvanized steel sections used for structural framing

3.13.16 undercut anchor

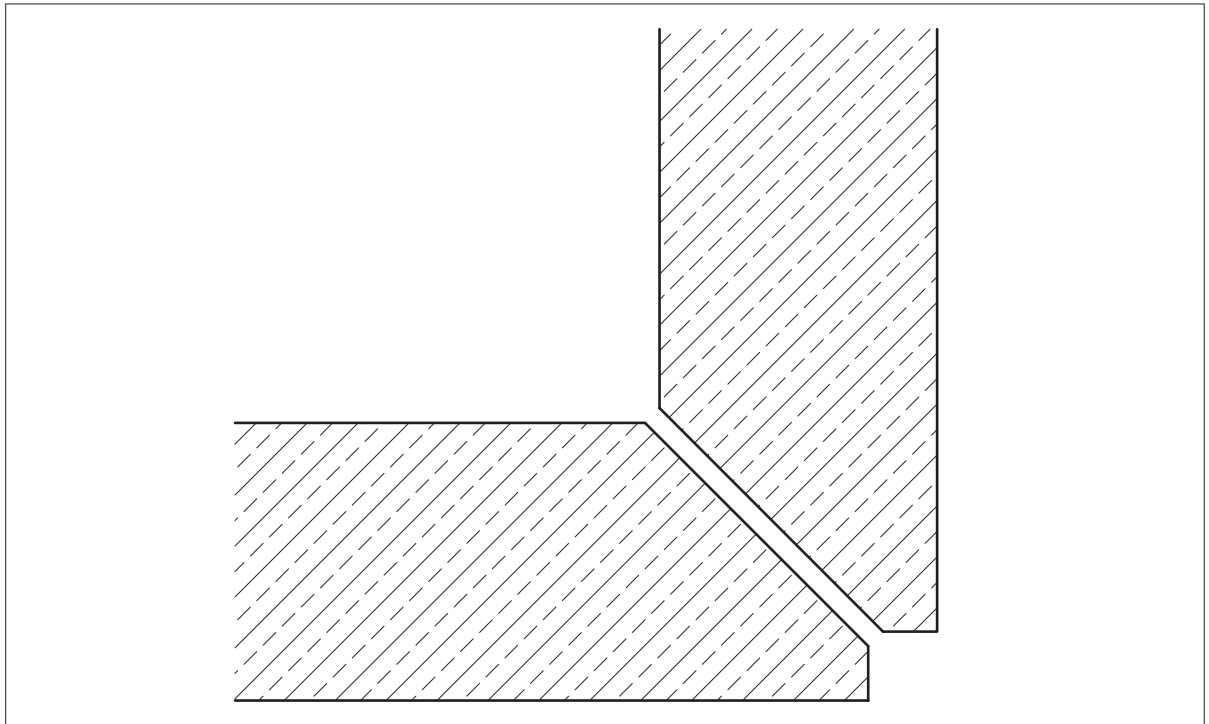
expansion anchor installed in a parallel hole with a flared base

NOTE With this type of anchor, PCT is very important and a regime of quality check anchor-proof loading in slabs is recommended prior to installation.

3.14 joints**3.14.1 birdsmouth joint**

mitred joint incorporating a rebate

NOTE See [Figure 1](#) for an example.

Figure 1 — *Birdsmouth joint***3.14.2 ceiling**

upper interior surface of a room

3.14.3 compression joint

joint designed specifically to accommodate pressure resulting from vertical shortening of the structure relative to the cladding or lining and thermal and moisture expansion of the stone

3.14.4 filled joint

joint that makes use of a jointing product to fill the gap between adjacent parts

3.14.5 movement joint

vertical joint that permits movement between adjacent parts

3.14.6 narrow joint

joint where the gap between two slabs is narrower than 5 mm, but does not have any added sealing element, relying only on closeness of fit to control the passage of water

3.15 lipping

offset of stone surface across a joint

3.16 packing (shim)

thin, possibly tapered or wedged piece of material, used to fill small gaps or spaces between lining elements, typically to support, adjust for better fit, or provide a level surface

3.17 pointing

material used to fill a joint between stones

3.18 production lot

unit of an assembly which is planned and manufactured with reference to a number

3.19 sealant

unformed flexible material applied in joints to prevent the passage of moisture, wind and dust

3.20 snags

minor defects in work

3.21 soffit

exposed horizontal or angled undersurface sloping to 75° to any form of construction works

3.22 stone specialist

individual or team experienced in:

- a) assessing the impact of geology on the likely performance of the stone;
- b) the stone extraction process and the impact on the stone's quality;
- c) selecting and testing stone, and evaluating results; and
- d) engineering the performance and design of natural stone cladding or lining

NOTE A stone specialist is not affiliated to the stone quarrying or stone fixing company.

4 Stone selection process**4.1 General***COMMENTARY ON 4.1*

The geological variations that make up the typical character of any natural stone that is proposed for the project can affect the performance. Stone is liable to vertical and horizontal variation within its mass; where beds are of sufficiently regular character and the stone has demonstrated a historical performance over several decades, selection does not present a difficulty. In other quarries, however, variations are such that individual blocks from which units are to be cut need to be considered on an individual basis.

Where the quality of blocks is not readily determined by inspection, a programme of testing should be proposed by a stone specialist so that suitable stones are selected for the project.

At the design concept stage and the pre-tender stage of a project, a shortlist of stone types should be prepared based on colour, texture, suitability, availability and cost.

The shortlist should be reduced at the pre-tender stage to stones that have been thoroughly researched to establish that:

- a) an acceptable and agreed range of aesthetic and geological features has been clearly documented, with the report of the agreed range of the reference samples forming part of the tender documentation;
- b) adequate quantities of block, allowing for manufacturing wastage, are available from the quarry to meet the construction programme;
- c) the largest and most frequently occurring project unit sizes are readily produced from blocks available from the selected quarry bed;
- d) the stone is evaluated in accordance with [BS EN 1469:2015](#);

NOTE 1 Attention is drawn to the requirements of the Declaration of Performance (DoP) and CE/UKCA marking [2].

NOTE 2 This demonstrates to the designer the declared values that may be used for the proposed application, and whether any additional testing is required before the tendering process.

- e) where stone is supplied with a resin-mesh backing, all supporting [BS EN 1469:2015](#) testing documentation shows testing of the stone without the resin-mesh backing, in accordance with [BS EN 1469:2015](#); and
- f) the surface finish selected for the project is consistent with the description in [BS EN 12670](#).

NOTE 3 Some surface finishing processes (e.g. flamed finish) can cause significant disruption to depth, with associated reduction in strength.

The overall project programme should take account of all the factors that could affect stone quarrying, design, manufacture and installation. Any additional testing regime and its effect on the programme should also be determined at a pre-contract award.

NOTE 4 Securing stone early in the programme allows for testing to be carried out on the block for the entire project, thereby reducing the risk of in-production rejections.

4.2 Stone samples and testing

4.2.1 Indicative stone samples

The initial selection for a shortlist of stones to be used on the project should be made from indicative samples supplied from current extraction, normally from the producing quarry. These samples should be supported with historical technical information showing test results in accordance with [BS EN 1469:2015](#), together with a list of reference buildings in the vicinity of the proposed site.

NOTE Indicative samples show the typical colour and surface texture of the stone and are normally approximately (150 × 150) mm. They cannot show the natural variations in visual appearance, colour, texture and geological features that are present in all natural stones.

Samples should be labelled in accordance with [BS EN 12440](#) and [BS EN 12670](#), i.e. traditional name, petrological family, and the location of the quarry, including country of origin. The surface finish or grit size used should be clearly stated to allow the specifier to accurately specify the stone.

4.2.2 Reference samples

Reference samples conforming to [BS EN 1469:2015](#) should be requested and include colour, texture, veining, shell content and the distribution, character and frequency of these, and all other features that are deemed to be part of the geological characteristics of the stone.

NOTE 1 Reference samples are normally held at the quarry or fabrication works and allow the designer to compare the samples to the production faces. A visit to the quarry also gives the designer an opportunity to look at the quantity and typical sizes of the block and assess their suitability for the project.

The number and size of control stone samples should be sufficient to show the designer the range and distribution of the geological characteristics of the stone and normally be made up of at least several square metres and a number of different slabs.

The reference samples should be viewed in accordance with [BS EN 1469:2015](#) and compared with the indicative samples by the designer with the assistance of a stone specialist, particularly for stone that does not have a proven history of use.

NOTE 2 To compare the reference samples to the actual production, it might be useful to look at the samples in an external environment in normal daylight conditions and in both dry and wet condition.

Once approved, the reference samples should be located at the manufacturing site and form part of the PCT for the project. Duplicate reference samples should be retained at the quarry (where separate from the production site) or the project, and be recorded, approved and photographed by the designer before dispatch.

NOTE 3 There are likely to be cost, programme and sustainability implications if the approved reference samples exclude some geological characteristics typically found in the stone.

If any dispute arises on site about the visual characteristics of the stones, the installed stone should be compared with the approved reference samples and viewed from at least 2 m.

If it is proposed to use a different stone, its declared values should be assessed in accordance with [BS EN 1469:2015](#).

4.2.3 Preliminary test information

NOTE 1 Attention is drawn to the requirements of the DoP and CE/UKCA marking [2].

To make an accurate assessment of the stone, all the tests should be presented in accordance with [BS EN 1469:2015](#).

The available data should include the statistically lower expected value (LEV) based on a 75% confidence level and the mean values that are representative of the stone currently being extracted or supplied for the project.

NOTE 2 Current as well as historical data gives a more representative assessment of the stone.

NOTE 3 To verify the data, copies of the laboratory test certificates might be requested.

4.2.4 Production control testing (PCT)

COMMENTARY ON 4.2.4

PCT by the manufacturer of the stone includes checking the manufacturing tolerance and visual appearance of every production lot and regular testing of the stone.

The minimum frequency of the PCT should be as shown in [Table 1](#).

NOTE The frequency of testing may be increased in response to such factors as changes in the typical geology and the opening of new areas of the quarry or mine.

Table 1 — PCT testing of characteristics of slabs for cladding or lining

Characteristics	Test method	PCT frequency
Geometrical characteristics	BS EN 13373	Every production lot
Visual appearance	BS EN 1469:2015	Every production lot
Flexural strength	BS EN 12372 ^{A)}	In accordance with the PCT system but at least every two years
Water absorption	BS EN 13755	In accordance with the PCT system but at least every two years
Apparent density and open porosity	BS EN 1936	In accordance with the PCT system but at least every two years
Petrographic examination	BS EN 12407	In accordance with the PCT system but at least every ten years
Breaking load at dowel hole	BS EN 13364	In accordance with the PCT system but at least every ten years

^{A)} BS 13161 is the preferred method for design purposes.

The manufacturing tolerances should be in accordance with [BS EN 1469:2015](#) and the measuring should be conducted in accordance with [BS EN 13373](#). The visual appearance check should confirm that the geological characteristics are in accordance with the approved reference sample and that the stone is free from vents, cracks, large fissures, sand and clay holes and other defects likely to affect durability and/or structural integrity. The manufacturer's procedures and policies should be:

- a) documented;

- b) available for inspection; and
- c) used to confirm that the actual stone selected in the reference sample is used on the project.

4.2.5 Initial testing for a project

A full set of results in accordance with [BS EN 1469:2015](#) should provide the technical properties of the stone.

NOTE 1 In some instances, the information produced from testing in accordance with [BS EN 1469:2015](#) can be sufficient for the project's design.

NOTE 2 Further testing, as instructed by the design team, is conducted if:

- a) the design warrants further testing for characteristics that are not available from the supplier;
- b) the stone has little or no history of being used in a similar application and environment; or
- c) the stone is being used in a wet or damp environment (see [4.2.8](#)).

The selection of samples for the initial testing should be undertaken by a stone specialist.

NOTE 3 The object of the sampling is to obtain stones that are representative of the geological characteristics of the selected bed in the quarry and of its variability, thereby confirming the initial testing of the stone as being suitable for the project.

4.2.6 Production control testing (PCT) for a project

COMMENTARY ON 4.2.6

PCT is additional to initial testing already completed to determine that the stone is suitable for its intended use.

The test regime and the selection of samples for PCT should be undertaken by a stone specialist at the early design stage of the project (pre-tender).

Test samples should be taken from at least three blocks or slabs to represent the geological range at the PCT frequency recommended below.

NOTE 1 The object of sampling is to obtain stones that are representative of the geological characteristics of the batch and of its variability.

The PCT should be in accordance with [Table 2](#).

The frequency of PCT should be determined by changes in geology at the mine/quarry and/or whether the stone is available from a stockyard or still to be extracted or as directed by the stone specialist.

The PCT frequency during production should be in accordance with [Table 2](#). Where test regime 3 is required or where a programme of production control is agreed, testing should be undertaken follows:

- a) before manufacture of the stone commences (0% of the stone manufactured): at the start of the project, conduct PCT to verify that the stone to be used for the actual manufacture produces results consistent with initial testing;

NOTE 2 If the first batch of testing covers the volume of stone for the entire project, selection of samples at 30%, 60%, 90% is not required.

- b) 10% of the stone manufactured at the earliest stage of production to verify that the stone is consistent with the initial selection;
- c) 30% of the stone manufactured to verify consistency of stone supplied for the project;
- d) 60% of the stone manufactured to verify consistency of stone supplied for the project; and

- e) 90% of the stone manufactured to verify consistency of stone supplied for the project.

If the results are found to be inconsistent with initial testing, the suitability of the stone should be reviewed for the project and production testing frequency modified, as appropriate, to re-establish confidence.

NOTE 3 [Table 2](#) sets out a stone testing regime in addition to the requirements [BS EN 1469:2015](#).

Table 2 — Stone testing regime in addition to the requirements of BS EN 1469:2015

Conformity	Good history of use in the application	Little previous history of use in the application
Conforms to BS EN 1469:2015 and provides declared values for all essential characteristics	Test regime 1	Test regime 2
Incomplete declared values for essential characteristics	Test regime 2	Test regime 3

Test regime 1: No PCT normally required, but limited testing for exceptional circumstances might be required.

Test regime 2: PCT of particular areas of concern where the declared values are missing or marginal to the project's requirements, e.g. strength test for a novel fixing system. If the stone has not been used in the application, other relevant tests might be appropriate.

Test regime 3: Extensive initial testing and PCT, including a complete initial type test in accordance with BS EN 1469:2015. Also, more regular PCT tests, such as density and porosity, water absorption, flexural strength, with additional tests relevant to the particular use/location, e.g. strength test for a novel fixing system, should be completed. If the stone has not been used in the application, other relevant durability tests might be appropriate.

4.2.7 Testing sample plan and report

Any sample submitted for testing should be representative of the typical properties of the stone. A sampling plan should be prepared which:

- identifies the approximate location from which the blocks or slabs have been extracted in the quarry or mine on a plan and where the samples are to be cut from the block; and
- shows the tests to be conducted and the number and sizes of the samples and the bed orientation.

NOTE More information on developing a sample plan is given in [BS EN 1469:2015](#) and [Annex A](#).

As the actual samples are cut, a sample report should be completed and included with the samples when they are sent to the testing laboratory to provide traceability.

4.2.8 Stone selection for wet and damp conditions

Where stone is to be used in bathrooms, showers, wet rooms, steam rooms and saunas, or in or around swimming pools, specialist advice should be sought.

NOTE 1 Repeated changes in moisture and temperature, cycles of wetting and drying and contact with chemicals in pool waters can affect the in-service performance of a particular stone, e.g. changes in the appearance of the stone can occur as a result of surface spalling, opening of natural veins or a change in colour.

The designer should establish whether a particular stone is suitable for use in the intended wet environment. Part of the assessment should incorporate a review of existing test data and, where appropriate, project-specific testing, including the following tests:

- [BS EN 14066](#);
- [BS EN 16140](#);
- [BS EN 12370](#);

- d) salt deposition potential incorporating a scanning electron microscope (SEM) analysis as part of the tide mark test; and

NOTE 2 Tide mark test includes the evaluation of salt deposition in proposed pool water and x10 concentrated pool water (with deionized water as a control) over a defined period with SEM analysis of surface post exposure.

- e) [BS EN 16306](#).

NOTE 3 Specialist advice can be sought regarding the development of the test programme and subsequent interpretation of the test results.

NOTE 4 Some of the tests are cyclical tests which require several weeks to complete, therefore adequate time is added in the testing schedule.

5 Designing internal cladding

5.1 General

At an early stage, the design team, in conjunction if necessary with a stone specialist, should set out and agree with those selecting and designing the cladding and lining, and their fixings, the functional requirements governing the principles of the design and the maximum movement of the cladding and lining for which allowance is to be made, together with the anticipated movement characteristics of the building frame (see [5.2](#)), including the anticipated shortening and how this is to be accommodated in the cladding and lining. The designer of the cladding and lining should develop the means of support and restraint, along with a fully coordinated design.

At the pre-tender stage, detailed drawings should be produced by the architect which show the following:

- a) setting out of stone slabs;
- b) movement joints and compression beds;
- c) layout of the fixings;
- d) cavity size; and
- e) relevant interface details.

Where stone is to be used in bathrooms, shower enclosures and wet rooms, a tanking system should be installed.

NOTE The type of tanking system selected is dependent on the type of backing structure and the preference of the designer.

Where stone is to be fixed to a partition wall, this should be designed in accordance with [BS 5234-1](#). The background should have minimal deflection and this should be no more than 1/500 of span.

A technical specification dealing with all aspects of the supply of the cladding should be prepared by the architect in consultation with a stone specialist. This should include definitions of the nature of any special additional tests required, e.g. impact and imposed loads, to be carried out on the cladding system in advance of the work.

Accuracy in the construction of the backing structure should be in accordance with [BS 5606](#) or as required by the project specification.

Once appointed, the stone contractor should produce working drawings showing how the stone cladding is fixed to the backing structure.

The design of the loadbearing and restraint fixings should take account of the structural tolerances set out in the project specification to avoid overstressing of the fixings (e.g. use of excessive

packing) and be manufactured to suit the as-built survey, which should be carried out at the earliest opportunity.

Account should be taken of the size and weight of prefabricated systems during transportation and handling.

Signs and other extraneous attachments, e.g. CCTV cameras, should be fixed directly to the main structure and taken through the cladding in such a manner as to avoid contact with the stone.

5.2 Movement in structures

COMMENTARY ON 5.2

Dimensional changes to a structure might occur for a variety of reasons.

[Table 3](#), which summarizes the origins of movement in various types of structure, should be used to assess possible building movements.

Table 3 — *Origins of movement in structures*

Source of movement	Type of structure			
	Steel framed	Concrete framed	Concrete blockwork	Fired clay masonry
Thermal movement	✓	✓	✓	✓
Differential settlement	✓	✓	✓	✓
Drying shrinkage	x	✓	✓	x
Moisture movement	x	✓	✓	✓
Creep	x	✓	✓	✓
Deflection (live and dead load)	✓	✓	✓	✓

NOTE The ticks indicate that the type of structure is affected by possible movement and the crosses mean that there is no movement to consider.

Dimensional changes in the parts of the building to which the cladding is applied should be taken into account when designing the joints between the cladding units and their fixings. These movements should be accommodated to avoid substantial stresses being imposed on units and their fixings.

NOTE 1 Stresses might be sufficient to fracture the projecting horizontal support or the units themselves, break the restraint cramps, or cause units to bow out from the main structure.

In addition, the design of fixings should be such as to allow freedom of vertical and lateral movement between structure and unit or, where this is not wholly possible, all forces should be allowed for in the design, including those caused by:

- a) physical movements of the structure;
- b) shrinkage of materials;
- c) thermal actions; or
- d) moisture.

NOTE 2 The assessment of the magnitude of such forces in combination is very complex and can only be estimated very approximately.

NOTE 3 Thermal movement might be a factor when stone is subjected to a greater range of temperatures, normally encountered in interiors such as glazed atriums in direct sunlight.

5.3 Deflection limits

The detailing of the stone fixing supports should be such that the deflection of the backing structure does not induce local prying stresses into the stone.

The deflection of any supporting structure/subframe should not exceed $L/500$ under serviceability loading, where L is the span of the subframe between support locations.

Any deflection of the backing structure under wind loading should be recovered upon removal of the load (i.e. deformation is not permanent).

5.4 Impact loading

COMMENTARY ON 5.4

For guidance on impact loading, see CWCT's Technical Note 75 [N1] and Technical Note 76 [N2].

5.4.1 Wind loads and air pressure changes

In large atrium areas, account should be taken of nominal wind loads based on air movements and a base pressure of 500 N/m^2 . If the atrium opening ratio is more than 5% in the completed design, cladding should be designed to resist wind loads, with project-specific wind loads derived in accordance with [BS EN 1991-1-4](#) and its National Annex.

NOTE If, for whatever reason, a project-specific wind load calculation cannot be completed, indicative wind loading presented in [BS 8298-2:2020](#), Table D.1 may be used for preliminary sizing of stone slabs. Where loading figures from [BS 8298-2:2020](#), Table D.1 are used, a partial load factor of 1.0 may be assumed.

5.4.2 Point loads

Where the use of access equipment at low level, e.g. ladders on shopfronts in malls, is anticipated, the cladding should be designed to resist a point load of not less than 500 N imposed at the most vulnerable location of the slab over an area of $(100 \times 100) \text{ mm}$. The height to which the stones have been designed for this point load should be recorded in the building operational manual for the use of subsequent occupiers.

Where appropriate, design loadings should be provided by the project maintenance consultant.

5.4.3 Barrier loading

Where cladding forms part of a barrier, balustrade or other element intended to retain, stop or guide people, the minimum imposed horizontal loads which the cladding is designed to, should be in accordance with [BS 6180](#) and [BS EN 1991-1-1](#) and its National Annex.

5.5 Material strength

5.5.1 General

The material strength should be determined from testing, taking account of the following:

- a) stone is a natural material and not subject to the same degree of control during its formation as that applied to factory-manufactured products, so typical geological variations can impact on the strength of individual stones;
- b) stone is a brittle material and cannot yield to accommodate localized high stresses (i.e. it breaks if it is overstressed);
- c) stone that has been tested is not necessarily representative of the stone that is to be put on the building, particularly if there is a limited programme of testing and no historical data;
- d) slab edges can be damaged during cutting, installation or in service, and this weakens the stone (the edges of the slab are where the highest stresses often occur);
- e) the cutting and drilling of stone can generate cracks and flaws around edges and fixing points, where the highest stresses are likely to be developed in service; and
- f) the surface finish.

NOTE Flaming can affect stone integrity.

5.5.2 Flexural strength testing

If project testing is conducted, this should be at or near the intended project thickness, with the stone in the same orientation (with regard to bedding/rift) and with the same finishes intended to be used on the project.

A set of at least ten specimens should be used to calculate the peak tensile stress in the specimen at the failure load. This stress should then be reported as the tensile strength of the stone.

NOTE For further information, see [BS EN 12372](#) and [BS EN 13161](#).

The strengths calculated from each set of test specimens should then be processed to determine both a mean strength and an LEV.

5.5.3 Fixing load testing

COMMENTARY ON 5.5.3

There is a variety of fixing types that can be used to secure stone cladding. Typical fixing methods include:

- *dowels;*
- *back anchors; and*
- *kerfs and mortices.*

The strength of fixings depends on their proximity to the edge and faces of the slab, and on their proximity to other fixings, e.g. if a bracket is secured to the reverse of a slab with two expansion anchors fitted a short distance apart, the strength of connection is less than twice the strength of a single anchor.

As a rule of thumb, smaller fixings (i.e. fixings which have the least physical engagement with the stone) tend to have the least resistance to pull out.

Regardless of the type of fixing, the strength of the fixing should be tested in stone at the intended project thickness, with the stone in the same orientation (with regard to bedding/rift) and with the same finishes intended to be used on the project. A minimum of ten specimens should be tested.

The breaking load of the fixing should be tested in accordance with:

- a) [BS EN 13364](#) (dowel fixings);
- b) [Annex B](#) (kerf and mortice fixings); and
- c) [Annex C](#), [Annex D](#) and [Annex E](#) (undercut fixings).

The results should be reported in the form of a mean strength and LEV.

NOTE Other discrete fixing types may be tested using the same basic principles set out in [BS EN 13364](#), with the fixing gripped using a suitable device for applying load to the fixing in question.

The test report should provide information about the dimensions of the fixing and the required hole, slot or mortice in the stone, to allow a third party to establish whether the fixing arrangement that was tested is representative of the intended application.

Any material or component that is applied between the fixing and the stone, such as mortar, sealant or a plastic/rubber tube, should be included in the test and clearly identified in the test report. Where a material is applied in a paste or semi-liquid form, time should be allowed for setting or curing of the material before testing in accordance with the manufacturer's instructions.

Where material is applied between the fixing and the stone, the designer should allow for the differential thermal expansion of material and the stone, which can induce stresses into the stone.

5.5.4 Bedding orientation

COMMENTARY ON 5.5.4

Some stones have pronounced bedding and their strength can vary markedly if measured parallel or perpendicular to the bedding. It is important to be able to identify stones that are likely to exhibit these characteristics and use them in the correct orientation. Simple strength testing in different orientations demonstrates whether a stone has a variation of properties with orientation.

The stone strength testing should be undertaken in the same bedding orientation as the intended use case.

5.5.5 Test sampling and historical data

COMMENTARY ON 5.5.5

The selection of the test samples and historical data is vital to understanding the technical properties of the stone. Ideally, historical test data are incorporated into the latest test results producing a representative mean and LEV characteristic value, in line with a recorded PCT in accordance with [BS EN 1469:2015](#).

Not all stones have this depth of data as, for example, stone might be from a new quarry or new bed in an existing quarry or otherwise imported.

Test data should reflect the representative range of the typical geology found in the stone sufficient for design purposes.

If a stone specialist selects test samples from at least three blocks or slabs to represent the geological range on the agreed reference samples, the results should be regarded as representative of the deposit, providing they are in line with a recorded PCT system.

NOTE If a stone specialist has not selected the test samples, even if the samples are taken from three or more blocks or slabs selected at least six months apart, there is still a risk that the test results might not be representative of the full range of geology.

5.6 Factors of safety

COMMENTARY ON 5.6

To make this British Standard compatible with the limit state design principles, the factors that were noted as “factors of safety” in [BS 8298-4](#) have been translated into “partial material factors”.

In accordance with limit state design principles, a level of reliability is provided within the design through the provision of two partial safety factors: partial load factor and partial material factor.

5.6.1 General

A “partial load factor”, γ_p , should be applied to the loading to account for the uncertainty in the loading.

A “partial material factor”, γ_m , should be applied to the material strength to account for the uncertainty in the material properties.

Both these partial factors should be applied in the stone design calculations to obtain design values.

NOTE Typical design checks are presented in [Annex D](#), with worked examples given in [Annex F](#) and [G](#).

5.6.2 Partial load factor, γ_f

The partial load factors should be in accordance with BS EN 1990:2002, Annex A.

A partial load factor should be applied to the loading:

$$F_d = \gamma_f F_k$$

where:

- γ_f is partial load factor;
 F_k is the characteristic load (mean or LEV); and
 F_d is the design load.

NOTE Serviceability limit state design is not applicable to stone cladding design. The partial load factor for point loads, as defined in 5.4.2 may be taken as 1.0 for ultimate limit state (ULS) design.

5.6.3 Partial material factor, γ_m

5.6.3.1 General

COMMENTARY ON 5.6.3.1

The partial material factors presented are only applicable to design within the scope of this standard. To this end, the partial material factors presented in this standard are based upon industry experience and a historical precedent of conformance. The partial material factors presented are not derived from a reliability-based analysis (see Foreword for further discussion).

A partial material factor should be applied to the material strength:

$$f_d = \frac{f_k}{\gamma_m}$$

where:

- f_k is the characteristic material strength (mean or LEV); and
 f_d is the design material strength.

The partial material factor should be selected based on the amount and nature of relevant test data that are available regarding the strength of the stone. Fewer data, of a less representative nature, should lead to the selection of a higher margin of safety.

The following issues should be taken into account when selecting the partial material factor:

- whether the available test data comprise a mean value or an LEV;
- whether the flexural strength is measured using a constant moment ([BS EN 13161](#)) or a concentrated load ([BS EN 12372](#));
- whether the test data are based on multiple samples or a limited set; and
- whether the stone samples tested are oriented consistent with the project design orientation.

The partial material factor for the design of stone slabs should be taken as:

$$\gamma_m = F_0 F_{LEV} F_{3-4} F_N F_\alpha$$

where:

- F_0 is the basic (minimum) partial material factor;
 F_{LEV} is the component which relates to the use of mean values or LEVs of strength;
 F_{3-4} is the component which relates to the use of constant moment or concentrated load testing;
 F_N is the component which relates to the number of sets of samples that were tested; and
 F_α is the component which relates to the orientation of the stone when tested.

Factors F_0 , F_{LEV} , F_{3-4} , F_N and F_α should be taken from [Table 4](#).

An alternative partial material factor to that determined with equation above should only be used where it has been proven by a stone specialist based on sufficient and suitable tests and calculations.

5.6.3.2 Test sampling and historical data

F_N should be taken as 1.0 in the following circumstances:

- if test data are available for three or more sets of samples selected by a stone specialist to represent at least the geological range on the agreed reference samples and are not out of date; and
- if historical test data are available in line with [BS EN 12372](#), [BS EN 13161](#) and [BS EN 1469:2015](#) for over ten years.

F_N should be taken as 1.35 if a) and b) do not apply; even if the samples are taken from three or more blocks or slabs selected at least six months apart, there is still a risk that the test results are not representative of the full range of geology, in which case factor F_N should be taken as 1.50 in the following circumstances:

- if the samples are selected from one set possibly taken from the same block or slab, so that there is a significant risk that the result is not truly representative of the full range of geology; or
- if the data are out of date or not in line with the PCT system, so that there is a significant risk that the results are not truly representative.

5.6.3.3 Components of partial material factor

For the determination of factors recommended in [5.6.2](#) and [5.6.3](#), [Table 4](#) should be used.

Where the partial material factor determined from [Table 4](#) is shown to be greater than nine, it should be assessed by a stone specialist familiar with the relevant stone/geological type and the requirements of engineering design.

NOTE The partial material factor may be varied where the stone specialist has access to or carried out sufficient and suitable tests and calculations to prove that a different partial material factor is appropriate and that best working practice is being followed in production and installation.

Table 4 — Components of overall factor of safety

Components	Overall factor of safety				
	F_0	F_{LEV}	F_{3-4}	F_N	F_α
Base factor of safety for flexure/bending (minimum for all stone types)	3.00	—	—	—	—
Base minimum factor for fixing breakout (minimum for all stone types):	3.00	—	—	—	—
• if using mean strength	—	1.40	—	—	—
• if using LEV of strength	—	1.00	—	—	—
• for strength measured using concentrated load to BS EN 12372 (three-point)	—	—	1.40	—	—
• for strength measured using constant moment to BS EN 13161 (four-point)	—	—	1.00	—	—
• if test data are limited to one set of samples, possibly taken from the same block or slab, or historical data are out of date	—	—	—	1.50	—
• if test data are available for three or more discrete sets of at least ten samples each, each set taken from blocks extracted at least six months apart or from differing locations in the quarry or mine and are not out of date	—	—	—	1.35	—

Table 4 — Components of overall factor of safety (continued)

Components	Overall factor of safety				
	F_0	F_{LEV}	F_{3-4}	F_N	F_α
• if test data are available for three or more sets of samples selected by a stone specialist to represent at least the geological range on the agreed reference samples and are not out of date	—	—	—	1.00	—
• if historical test data are available in line with BS EN 12372, BS EN 13161 and BS EN 1469:2015 for over ten years	—	—	—	1.00	—
• if stone subject to variation of properties with orientation, but cut in unknown orientation	—	—	—	—	1.40
• if stone subject to variation of properties with orientation, but cut in same orientation as intended for use on project	—	—	—	—	1.00
• if stone not subject to variation of properties with orientation	—	—	—	—	1.00
<i>NOTE All data to be for stone extracted from the same bed of the same quarry.</i>					

5.7 Impact

COMMENTARY ON 5.7

All exposed building surfaces are liable to impact, such as accidental slips or trips, or impacts from cleaning equipment. Impacts can be loosely classified into two types: soft body and hard body. As a general rule, impacts are likely to be more severe at low level, but stone which falls from a height is more likely to cause a serious injury.

The specifier should avoid specifying high levels of impact performance in areas that are unlikely to be impacted in service. Each part of the internal stone cladding should be assessed separately and, if possible, other ways of reducing the risk of impact identified, rather than trying to design the entirety of the interior stone cladding to resist any level of impact that can be imagined.

The soft body impact risk for each project should be assessed and the risk categorized in accordance with CWCT's *Technical Note 75* [N1] and tested to CWCT's *Technical Note 76* [N2]. When specified by the design team, testing should be carried out for specific systems and the impact resistance of the stone cladding improved in accordance with CWCT's *Technical Note 76* [N2].

NOTE 1 Hard body impacts are associated with smaller, lighter objects that have less mass but might have hard corners or protrusions, e.g. cleaning equipment or materials being moved in trolleys. The energy associated with a hard body impact is much less, but there is a greater risk of causing localized surface damage. Hard body impacts are not covered by this part of BS 8298.

Tools used at height should be secured so that they do not fall and cause impact damage to a vertical surface. Access, cleaning and material handling equipment should be provided with suitable padding or cushioning to prevent hard contact.

NOTE 2 Soft body impact testing to BS 8200 was historically carried out using a sphero-conical bag filled with glass beads, to a mass of 50 kg. It is likely in the long term that this might be replaced by the double-tyre impactor once sufficient research and software development have been proven for stone.

The specifier should establish the need for project-specific impact testing in any of the following situations:

- a) where the thickness of the stone is less than 50 mm, particularly if the stone mean flexural strength is less than 5 MPa;

- b) where the span of a stone slab between fixings exceeds 600 mm in any direction;
- c) where the length of the slab exceeds 900 mm in any direction;
- d) where the slabs have decorative features, such as grooves or rebated edges; and
- e) where there is a higher risk of misuse of the building.

If energy absorbing pads are used behind the stone slab, these should have a layer of resilient material between the pad and the stone to prevent hard contact of stone against metal.

NOTE 3 To resist the project impact energy, pads or a stiffening structure may be placed behind the slab to improve the impact performance of the cladding.

If impact energies are within 1.5 m of the floor, thicker stone or a different type of interior stone cladding should be used for locations that impact resistance.

Resistance to impact should be improved by one or more of the following measures, as necessary:

- 1) making the stone thicker;
- 2) using fixings which minimize the amount of machining or drilling of the stone;
- 3) mounting the stone in such a way that the structural supports absorb some of the impact energy;
- 4) avoiding the working of slab edges around fixing locations; and
- 5) minimizing the span between fixings (putting fixings on the long edges rather than the short edges).

5.8 Staining and changes in appearance

The water absorption and porosity characteristics and the design detailing of natural stone should be taken into account, along with the installation environment.

NOTE 1 Some stone types can be susceptible to staining and an appropriate impregnator can be applied.

NOTE 2 Bedding, pointing and impregnating treatment might, in some cases, result in staining or surface darkening.

The surface should be correctly maintained, and the impregnator reapplied at the appropriate intervals, to avoid staining of the stone.

If the stone is susceptible to staining, it should be tested in accordance with [BS EN 16301](#).

NOTE 3 Failure to correctly maintain the stone might result in the impregnation being removed and the stone being susceptible to water and staining.

NOTE 4 A polished stone provides a greater resistance to the absorption of water and other liquids, but other performance factors might be affected.

5.9 Cavities

The appointed building authority should be engaged with to establish the criteria under which the particular facade is to be assessed.

If required by the appointed building authority, the building designer should plan for the provision of cavity barriers and fire stops which are practical to install and allow the inhibition of, for instance, fire spread within concealed cavities.

The structure at floor levels should accommodate the fixing of the cavity barrier, both open and closed state, while maintaining the provision for loadbearing fixings. These same criteria should be met when lining an existing structure.

The cavity barrier should be appropriate for the type of stone being used.