



BSI Standards Publication

Design and installation of natural stone cladding and lining

Part 2: Traditional handset external cladding —
Code of practice

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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 31 December 2020. 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This part of BS 8298 supersedes BS 8298-2:2010, which is withdrawn. Together with [BS 8298-3:2020](#) and [BS 8298-4:2020](#) this part supersedes BS 8298-1:2010, which is withdrawn.

Relationship with other publications

BS 8298, *Design and installation of natural stone cladding and lining*, will eventually be issued in four parts:

- Part 2: *Traditional handset external cladding – Code of practice*;
- Part 3: *Stone-faced precast concrete cladding systems – Code of practice*;
- Part 4: *Stone cladding on rainscreen support systems – Code of practice*; and
- Part 5: *Natural stone lining – Code of practice*.¹⁾

The recommendations for production control testing that were previously given in Part 1: *General* have or will be incorporated into Parts 2 to 5, so that Part 1 is withdrawn.

Information about this document

This is a full revision of the standard, and introduces the following principal changes:

- the incorporation of the recommendations for production control testing from BS 8298-1:2010;
- the addition of several figures to illustrate key details; and
- the structural design of the stone has been updated to follow the principles of limit state design.

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 1990:2002+A1, Annex D. 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This publication can be withdrawn, revised, partially superseded or superseded.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.

Assessed capability. Users of this British Standard are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.

¹⁾ In preparation.

Use of this document

As a code of practice, this part of BS 8298 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

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

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

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

1 Scope

This part of BS 8298 gives recommendations for the design, installation and maintenance of traditional handset external cladding of natural stone held directly to a structural backing structure by metal fixings.

It covers:

- a) the sampling of stone for testing and production control testing (PCT);
- b) the provisions necessary for the cladding to perform its function satisfactorily;
- c) the materials and methods most frequently used for stonework; and
- d) the use of thermal insulation behind external cladding.

Loadbearing masonry or cladding held only by adhesion is not covered, nor is any type of cladding supported or held in position around the perimeter of stones or series of stones by metal framing (e.g. rainscreen). This document is not applicable to seismic loading or enhanced security scenarios (such as blast).

NOTE The general principles for cladding also apply to soffits and sloping surfaces.

Different cladding and lining methods are covered in the other parts of BS 8298 (see Foreword).

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 of this document²⁾. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

[BS 5606](#), *Guide to accuracy in building*

[BS 5642-1](#), *Sills, copings and cappings – Part 1: Specification for window sills of precast concrete, cast stone, clayware, slate and natural stone*

[BS 5642-2](#), *Sills, copings and cappings – Part 2: Specification for copings and cappings of precast concrete, cast stone, clayware, slate and natural stone*

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

[BS 6100-1](#), *Building and civil engineering – Vocabulary – Part 1: General terms*

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

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

[BS 8221-1](#), *Code of practice for cleaning and surface repair of buildings – Part 1: Cleaning of natural stones, brick, terracotta and concrete*

[BS 8221-2](#), *Code of practice for cleaning and surface repair of buildings – Part 2: Surface repair of natural stones, brick and terracotta*

[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*

²⁾ 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, *Natural stone products – Slabs for cladding – 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 1991-1-3, *Eurocode 1: Actions on structures – Part 1-3: General actions – Snow loads*
- 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 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 12059, *Natural stone products – Dimensional stone work – Requirements*
- BS EN 12370, *Natural stone test methods – Determination of resistance to salt crystalization*
- BS EN 12371, *Natural stone test methods – Determination of frost resistance*
- 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 ISO 11600, *Building construction – Jointing products – Classification and requirements for sealants*
- 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 1991-1-3, *UK National Annex to Eurocode 1: Actions on structures – Part 1-3: General actions – Snow loads*
- NA to BS EN 1991-1-4, *UK National Annex to Eurocode 1: Actions on structures – Part 1-4: General actions – Wind actions*

PD 6484, *Commentary on corrosion at bimetallic contacts and its alleviation*

Other publications

[N1] CWCT TN 75, *Impact performance of building envelopes: Guidance on specifications*. Technical Note 75. Bath: Centre for Window and Cladding Technology. 2012.

[N2] CWCT TN 76, *Impact performance of building envelopes: Method for impact testing cladding panels*. Technical Note 76. Bath: Centre for Window and Cladding Technology. 2012.

3 Terms and definitions

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

3.1 Anchors

3.1.1 anchor

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

3.1.2 back anchor (expansive)

anchor installed in a parallel hole (held by frictional restraint only)

NOTE With this type of anchor, production control testing is very important and a regime of quality check anchor proof loading in panels is recommended prior to installation.

3.1.3 back anchor (non-expansive)

anchor installed in a parallel hole (held with or without cement/resin), which is often cranked

3.1.4 expansion anchor

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

3.1.5 hollow bolt

stainless-steel expansion bolt for hollow steel sections

3.1.6 self-tapping screw

screw that taps its own hole

NOTE Also known as "self-drilling".

3.1.7 steel frame system (SFS)

cold formed galvanized steel sections used for structural framing

3.2 backer rod

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

3.3 backing structure

secondary frame (e.g. subframe, SFS) to which stone is fixed, generally located between the primary structure and the stone

3.4 backing wall

layer of the wall that provides airtightness and water tightness 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 a traditional handset cladding is added.

3.5 bimetallic corrosion

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

3.6 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; or
- restrict the movement of smoke or flame within a cavity

[SOURCE: Approved Document B [1]]

3.7 characteristic value (f_k, F_k, R_k)

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

NOTE See commentary on [5.5.7](#).

3.8 cladding

external covering to a structure

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

3.13.1 fixing

combination of bracket and fastener/anchors

3.13.2 cladding fixing

device to support or tie back cladding units to the structure

3.13.3 combined loadbearing and restraint fixing

device that transfers the self-weight of one or more cladding 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 face fixing

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

3.13.6 fastener

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

3.13.7 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

3.13.8 packer (shim)

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

3.13.9 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

3.13.10 restraint fixing

device to restrain or tie back cladding units to the structure

NOTE The term "tying back fixing" is deprecated.

3.13.11 soffit fixing

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

3.13.12 stone fixing

fixing device to attach stone facing onto a backing panel

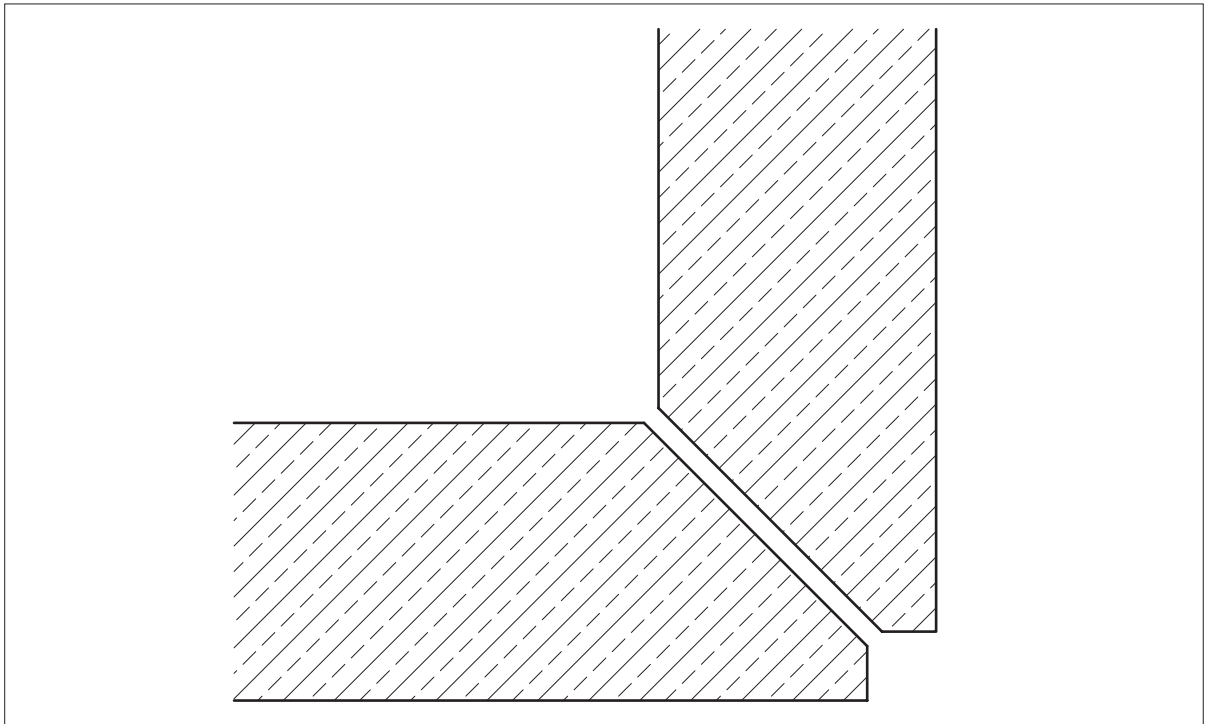
NOTE Such fixings are generally dual purpose, providing both support and restraint.

3.14 handset cladding

stone panels 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

3.15 Joints**3.15.1 birdsmouth joint**

mitred joint incorporating a rebate (see [Figure 1](#))

Figure 1 — *Birdsmouth joint***3.15.2 compression joint**

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

3.15.3 filled joint

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

3.15.4 movement joint

vertical joint that permits movement between adjacent parts

3.15.5 narrow joint

joint where the gap between two panels 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

3.15.6 open joint

joint not closed by any sealing element, thereby permitting the free passage of air and water through the joint

3.16 lipping

offset of stone surface across joint

3.17 pilaster

pier or part of a column attached to a wall

3.18 plinth

lowest stone course(s) typically below damp-proof course (d.p.c.) level

3.19 production lot

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

3.20 pointing

material used to fill a joint between stones

3.21 sealant

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

3.22 snags

minor defects in work

3.23 soffit

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

3.24 stall riser

upright part of a glazed front between the pavement and window sill or a low cladding unit located below a ground floor window

3.25 stone specialist

individual or team who is not affiliated to the stone quarrying or stone fixing company and who is experienced in:

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

3.26 Surfaces/finishes**3.26.1 flamed finish**

surface finish obtained by thermal treatment of the stone using a high temperature flame

3.26.2 honed finish

surface finish obtained by grinding the stone to produce a consistent surface, depending on the specified grit size

3.26.3 riven finish

roughened surface finish produced by splitting stone along natural cleavage or bedding planes

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

It is vital to understand the geological variations that make up the typical character of any natural stone that is proposed for the project. 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 cannot readily be determined by inspection, a programme of testing should be proposed by a stone specialist to check that suitable stones are used on 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 one or two 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 can be readily produced from blocks available from the selected quarry bed;
- d) a Declaration of Performance (DoP) is provided in accordance with BS EN 1469 to demonstrate to the designer that the stone is suitable for the proposed application, and if there are any concerns about the DoP results, a programme of initial testing is instigated before the tendering process;
- e) where stone is supplied with a resin-mesh backing, all supporting documentation shows testing of the stone without the backing as this does not conform to BS EN 1469;
- f) where horizontal surfaces are included in the design, these meet the technical requirements in BS EN 12059; and
- g) the surface finish selected for the project is consistent with the description in BS EN 12670.

NOTE 1 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 2 Securing stone early in the programme allows for the 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, 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 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 The reference samples are normally held at the quarry or fabrication works and allow the designer to compare these samples with 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 to compare these with the project requirements.

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 should normally be made up of at least several square metres and a number of different panels.

The reference samples should be viewed in accordance with BS EN 1469 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 with the actual production, it might be sensible to look at the samples in an external environment in normal daylight conditions and in dry, then wet conditions.

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 despatch.

NOTE 3 There are likely to be cost and even 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 stone, the installed stone should be compared with the approved reference samples and viewed from at least 2 m.

If, for whatever reason, it is proposed to use a different stone, its suitability should be verified in accordance with BS EN 1469.

4.2.3 Declaration of Performance (DoP)

COMMENTARY ON 4.2.3

The DoP is part of the European Construction Products Regulation [2] and is available for all stone placed on the market in the UK and the EU. The DoP's data are intended to be consistent across all member countries.

To make an accurate assessment of the suitability of the stone, the DoP should contain all the test requirements specified by BS EN 1469.

The DOP should be prepared using all available reliable data so that the statistically lower expected value (LEV) based on a 75% confidence level and the mean figures are truly representative of the stone.

NOTE 1 A DoP containing current, as well as historical, data gives a more representative assessment of the stone.

NOTE 2 To verify that the DoP is based on reliable data, copies of the test certificate could be requested.

4.2.4 Production control testing (PCT)

COMMENTARY ON 4.2.4

As part of the DoP, the manufacturer of the stone maintains PCT, which 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](#), but 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.

The manufacturing tolerances should be in accordance with BS EN 1469, and in the case of a dispute, the measuring should be conducted in accordance with BS EN 13373. The visual appearance check should verify 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:

- a) be documented in a systematic manner;
- b) be available for inspection; and
- c) verify that the actual stone selected in the reference sample is used on the project.

Table 1 — *PCT testing of characteristics of panels for cladding*

Characteristics	Test method	PCT frequency
Geometrical characteristics	BS EN 13373	Every production lot
Visual appearance	BS EN 1469	
Flexural strength	BS EN 13161 or BS EN 12372	In accordance with the PCT system but at least every 2 years
Water absorption	BS EN 13755	
Apparent density and open porosity	BS EN 1936	
Petrographic examination	BS EN 12407	In accordance with the PCT system but at least every 10 years
Breaking load at dowel hole	BS EN 13364	
Frost resistance	BS EN 12371	

4.2.5 Initial testing for a project

The DoP containing a full set of results should provide a good indication of the stone's technical properties.

NOTE 1 In many cases the DoP is sufficient for the project's design.

Initial testing should be conducted if:

- a) the design warrants further testing for characteristics that do not form part of the DoP and are not available from the supplier; or
- b) the stone has little or no history of being used in a similar application and environment.

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

NOTE 2 The objective 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, and thereby check that the initial testing of the stone confirms that it is suitable for the project.

4.2.6 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 normally be taken from at least three blocks or panels to represent the geological range at the PCT frequency recommended in a) to e) below.

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

The frequency of the 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](#) and:

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

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 cladding production to verify that the stone is consistent with the initial selection;
- c) 30% of the stone manufactured to verify consistency of cladding supplied for the project;
- d) 60% of the stone manufactured to verify consistency of cladding supplied for the project; and
- e) 90% of the stone manufactured to verify consistency of cladding 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 the frequency of production testing modified as appropriate to re-establish confidence.

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

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

Conformity	Good history of use in the vicinity	Little previous history of use in the vicinity
Conforms to BS EN 1469 and a DoP 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 or freeze-thaw tests. If the stone has not been used in the vicinity, other relevant durability tests might be appropriate if the project is in a susceptible location.		
Test regime 3: Extensive initial testing and PCT, including a complete initial type test in accordance with BS EN 1469. 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 or freeze-thaw tests, should be completed. If the stone has not been used in the vicinity, other relevant durability tests might be appropriate if the project is in a susceptible location.		

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:

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

NOTE More information on developing a sampling plan is available in BS EN 1469 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 Testing for in-service performance

4.2.8.1 Thermal and moisture cycling (“bowing”)

COMMENTARY ON 4.2.8.1

In some cases, natural stone can undergo deformation due to moisture and thermal influences, resulting in bowing or dishing. This phenomenon is well documented for certain types of marble, but can also occur, albeit rarely, with sandstones and limestones.

The designer should establish whether a particular stone has been used previously for cladding and at what panel size and thickness as large, thin panels tend to be more susceptible to bowing.

NOTE BS EN 1469 specifies a test method (BS EN 16306) to evaluate the resistance of marble to thermal and moisture cycles.

4.2.8.2 Durability

4.2.8.2.1 Frost action

Some stones can reduce in strength when subjected to a protracted number of freeze-thaw cycles, which can occur in some parts of the UK, so this reduction in strength should be factored into the cladding design as it could affect thickness and impact on the factor of safety used (see [5.6.4, Table 4](#)).

Designers should evaluate available test results in accordance with BS EN 12371 to establish whether the stone is affected by freeze/thaw cycling.

Where freeze-thaw conditions are anticipated, stone used as cladding should conform to BS EN 1469 (i.e. subjected to a minimum of 14 cycles of freeze/thaw) (see also [5.5.6](#)).

NOTE Some protection can be incorporated into the design, such as the use of lead flashings on copings, cornices, strings or other projecting courses, to avoid saturation on horizontal surfaces and subsequent frost damage.

Where protection is not provided to sills and copings, the stone selected should conform to BS EN 12059 (i.e. subjected to a minimum of 48 cycles of freeze/thaw).

4.2.8.2.2 Salt crystallization

COMMENTARY ON 4.2.8.2.2

Over the last two centuries the release of sulfur dioxides from the uncontrolled burning of fossil fuels in the UK has caused significant damage to stones, particularly less durable limestones and sometimes sandstones.

In modern times, due to the stricter regulations on industrial emissions, pollutants from fossil fuels are now at a very low level and the detrimental effects are no longer considered to be an issue.

Cladding can still be affected by salt crystallization deterioration in certain exposure environments (e.g. plinth courses affected by de-icing salts or locations in coastal areas affected by sea spray).

The susceptibility of stone to salt crystallization should, where necessary, be determined in accordance with BS EN 12370. Where the stone is found to be susceptible to crystallization, specialist advice should be obtained.

5 Designing external cladding

5.1 General

At an early stage, the structural engineer and architect designing the building should set out and agree, with those selecting and designing both the cladding stones and their fixings, the functional requirements governing the principles of the design and the maximum movement of the cladding

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. The designer of the cladding system should develop the means of support and restraint, while ensuring a fully coordinated design between all involved.

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

- a) setting out of stone panels;
- b) movement joints and compression beds;
- c) cavity trays;
- d) cavity barriers;
- e) layout of the fixings; and
- f) insulation/cavity size.

The design team should take into account that stone cladding might not prevent moisture penetration and a waterproofing barrier might be required.

A technical specification dealing with all aspects of the supply of the cladding should be prepared by the architect in consultation with appropriate stone specialists, and 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.

NOTE 1 Accuracy in the construction of the backing structure is essential.

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

Signs and other extraneous attachments, e.g. street lighting and 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 cladding.

Lightning conductors should be detailed to prevent staining or damage to the cladding.

NOTE 2 The Building Regulations [3-7] limit the use of combustible materials in certain circumstances.

5.2 Movement in structures

COMMENTARY ON 5.2

Dimensional changes might arise for a variety of reasons.

Table 3, which summarizes the origins of movement in various types of structures, should be used to assess possible building movements.

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, which could 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.

Table 3 — *Origins of movement in structures*

Source of movement	Type of structure			
	Steel framed	Concrete framed	Concrete and calcium silicate masonry	Fired clay masonry
Elastic deformation	✓	✓	✓	✓
Thermal movement	✓	✓	✓	✓
Differential settlement	✓	✓	✓	✓
Drying shrinkage	×	✓	✓	×
Moisture movement	×	✓	✓	✓
Creep	×	✓	✓	✓
Long-term expansion	×	×	×	✓
Deflection (live and dead load)	✓	✓	✓	✓

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 Annex B gives a worked example of the calculation of thermal movement. The information is of a general nature and is intended to outline the most significant factors affecting movement in various supporting structures and claddings, and to provide typical properties of materials to enable some assessment of movements to be made.

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 Loading

5.4.1 Wind loads

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 1 If, for whatever reason, a project-specific wind load calculation cannot be completed, the indicative wind loading presented in Table D.1 may be used for preliminary sizing of stone panels. Where loading figures from Table D.1 are used, a partial load factor of 1.0 may be assumed.

NOTE 2 Wind loading on parapets, free-standing walls and canopies is typically greater than the general building envelope.

5.4.2 Snow loads

Cladding should be designed to resist snow loads, with project-specific snow loads derived in accordance with BS EN 1991-1-3 and its National Annex.

5.4.3 Point loads

Where the use of access equipment at low level, e.g. ladders on shopfronts, 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 panel over an area of (100 × 100) 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.

5.4.4 Barrier loading

Where cladding forms part of a barrier or balustrade, designers should take account of the barrier loading given in [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 that can be 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 is liable to chemical changes, both in the ground and in service, due to weathering (for example, dissolution of minerals by water action or degradation of minerals due to exposure to pollutants), and this can reduce the strength of stone over time;
- d) stone can crack over time (microcracks), both in the ground and in service, as a result of geological forces, thermal/moisture cycling or cyclic wind loads, and this reduces the strength of the stone over time;
- e) stone that was 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;
- f) panel edges can be damaged during cutting, installation or in service, and this weakens the stone (the edges of the panel are where the highest stresses often occur); and
- g) 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.

NOTE See Clause 4, particularly [4.2.2](#) to [4.2.7](#).

5.5.2 Flexural strength testing

The stone flexural strength should be determined in accordance with BS EN 13161 (constant moment, 4-point bending) or BS EN 12372.

NOTE BS EN 1469 requires that BS EN 12372 (concentrated load, 3-point bending) is followed. However, the BS EN 13161 method exerts stress through a greater volume of the stone sample, increasing the probability of the weakest part of the sample being tested. The BS EN 13161 method is a more representative measure of the stone's flexural strength in a cladding scenario than the BS EN 12372 method.

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 (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 a lower expected value (LEV).

5.5.3 Fixing breakout 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; and*
- *kerfs and mortices.*

The strength of fixings depends on their proximity to the edge and faces of the panel, and on their proximity to other fixings, e.g. if a bracket is secured to the reverse of a panel 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); and
- b) [Annex C](#) (kerf clip or channel fixings).

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

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 sufficient 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, sufficient time should be allowed for setting or curing of the material before testing.

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

5.5.4 Wet and dry testing

COMMENTARY ON 5.5.4

Testing is normally carried out in dry conditions in accordance with the test methods in both BS EN 12372 and BS EN 13161, and BS EN 1469 requires that dry results be stated. However, for

cladding of 50 mm or less and/or if the cladding is likely to be saturated, it is often appropriate to test wet samples. This is necessary where it is known that the wet strength of a particular stone type is likely to be lower.

Where thin stone is to be used in the cladding system it is likely to be saturated in use, potentially resulting in a loss of strength, so the stone should be tested in both wet and dry conditions.

5.5.5 Bedding orientation

COMMENTARY ON 5.5.5

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.

5.5.6 Susceptibility to freeze-thaw

If the project is in a location where the stone is likely to be subjected to temperatures that are sufficiently low to freeze water inside the stone, the susceptibility to a reduction in its strength from this freeze-thaw process should be assessed.

The samples to be tested should be consistently representative of the stone's geology.

For coping stones and other horizontal surfaces, the stone should be tested in accordance with BS EN 12059, which requires a higher number of cycles of frost testing to be completed.

5.5.7 Test sampling and historical data

COMMENTARY ON 5.5.7

The selection of the test samples and historical data is vital to understanding the technical properties of the stone. Ideally, the stone would have a good history of use in the local area, historical test data that are incorporated into the latest test results producing a representative mean and LEV characteristic value, in line with a recorded PCT (see BS EN 1469).

Not all stones have this depth of data as, for example, stone might be from a new quarry or a new bed in an existing quarry or otherwise imported. It is still very important and reassuring to establish test data based on a representative range of the typical geology found in the stone if there is no full and valid DoP.

If a stone specialist selects test samples from at least three blocks or panels 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 panels 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 the 2010 edition 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: the partial load factor and the 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 in accordance with [Annex D](#), to obtain design values.

NOTE Worked examples are given in [Annex E](#).

5.6.2 Partial load factor, γ_f

The partial load factor should be determined in accordance with BS EN 1990:2002+A1, Annex A.

A partial load factor should be applied to the loading:

$$F_d = \gamma_f F_k \quad (1)$$

where:

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

Unless noted otherwise, the partial load factor, γ_f , for live loads (wind and snow) should be taken as 1.5 for ultimate limit state (ULS) design.

NOTE 1 Serviceability limit state (SLS) design is not applicable to stone cladding design.

NOTE 2 The partial load factor for point loads, as defined in [5.4.3](#), may be taken as 1.0 for 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 British Standard. To this end, the partial material factors presented are based upon industry experience and a historical precedent of conformity. The partial material factors presented are not derived from a reliability-based analysis. See the Foreword for further information.

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

$$f_d = \frac{f_k}{\gamma_m} \quad (2)$$

where:

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

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.