BS 8298-1:2010

BSI Standards Publication

Code of practice for the design and installation of natural stone cladding and lining –

Part 1: General

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Contents

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Foreword

Publishing information

This part of BS 8298 was published by BSI and came into effect on 31 December 2010. It was prepared by Technical Committee B/545, *Natural stone*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

Together with BS 8298-2, BS 8298-3, BS 8298-4 and BS 8298-5 [1)], this part of BS 8298 supersedes BS 8298:1994, which is withdrawn.

Relationship with other publications

BS 8298, *Code of practice for the design and installation of natural stone cladding and lining*, will be issued in five parts:

- *Part 1: General*;
- *Part 2: Traditional handset external cladding*;
- *Part 3: Stone-faced pre-cast concrete cladding systems*;
- *Part 4: Rainscreen and stone on metal frame cladding systems*;
- *Part 5: Internal linings*.[1)]

Information about this document

Stone, in the form of thin slabs of modest dimensions, has been used for centuries as a decorative facing to backgrounds of stone and brickwork. With framed structures, where the loads are carried by the frame and not by the external walling, the materials or combinations of materials used to cover the structural framework are referred to as cladding.

Cladding, in the form described in BS 8298, requires care to ensure permanent fixing and water management. Adequate precautions have to be taken to provide for permanent and temporary movements of the structure due to shrinkage and elastic deformation under load. Movement due to temperature and other factors also has to be taken into account.

BS 8298 describes the provisions necessary for the cladding to perform its function satisfactorily. It gives the minimum standards required and the materials and methods most frequently used for stonework. This part deals with materials used for cladding including the fixings and sealants as well as the natural stone. Other methods are covered in other parts. The parts of BS 8298 have been updated to reflect general changes in the types of cladding used and, in particular, the types of fixing system.

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 in 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.

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 mechanically fixed facing units of natural stone as a cladding held to a structural background by metal fixings.

As the "General" part of the BS 8298 series, this standard covers aspects of the other parts of the series, i.e.:

a) traditional handset external cladding;

b) stone-faced pre-cast concrete cladding systems;

c) rainscreen and stone on metal frame cladding systems; and

d) internal linings.

NOTE 1 The terms and definitions given apply to all parts of BS 8298.

Recommendations are given regarding movement of the structure, which might occur for one or more reasons, so that such dimensional changes can be accommodated.

NOTE 2 The general principles for cladding also apply to soffits and sloping surfaces.

BS 8298 does not cover stone veneer composite panels or the use of stone cladding as permanent formwork to in-situ concrete.

2 Normative references

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

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 6398, *Specification for bitumen damp-proof courses for masonry*

BS 6515:1984, *Specification for polyethylene damp-proof courses for masonry*

BS 8221-1:2000, *Code of practice for cleaning and surface repair of buildings – Part 1: Cleaning of natural stones, brick, terracotta and concrete*

BS 8221-2:2000, *Code of practice for cleaning and surface repair of buildings – Part 2: Surface repair of natural stones, brick and terracotta*

BS 8298 (all parts), *Code of practice for the design and installation of natural stone cladding and lining*

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*

BS EN 459-1, *Building lime – Part 1: Definitions, specifications and conformity criteria*

BS EN 485-1:2008+A1:2009, *Aluminium and aluminium alloys – Sheet, strip and plate – Technical conditions for inspection and delivery*

BS EN 485-2:2008, *Aluminium and aluminium alloys – Sheet, strip and plate – Part 2: Mechanical properties*

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 998-1, *Specification for mortar for masonry – Part 1: Rendering and plastering mortar*

BS EN 1008, *Mixing water for concrete – Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*

BS EN 1469:2004, *Natural stone products – Slabs for cladding – Requirements*

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

BS EN 1996-2, *Eurocode 6 – Design of masonry structures – Part 2: Design considerations, selection of materials and execution of masonry*

BS EN 10088-1, *Stainless steels – Part 1: List of 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 12371, *Natural stone test methods – Determination of frost resistance*

BS EN 12407, *Natural stone test methods – Petrographic examination*

BS EN 12440, *Natural stone – Denomination criteria*

BS EN 12588:2006, *Lead and lead alloys – Rolled lead sheet for building purposes*

BS EN 12600, *Eurocode 6 – Design of masonry structures – Part 2: Design considerations, selection of materials and execution of masonry*

BS EN 12670, *Natural stone – Terminology*

BS EN 12811-1, *Temporary works equipment – Part 1: Scaffolds – Performance requirements and general design*

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 13279-1, *Gypsum binders and gypsum plasters – Part 1: Definitions and requirements*

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 14019, *Curtain walling – Impact resistance – Performance requirements*

BS EN ISO 11600, *Building construction – Jointing products – Classification and requirements for sealants*

PD 6484:1979, *Commentary on corrosion at bimetallic contacts and its alleviation*

3 Terms and definitions

For the purposes of all parts of this British Standard, the terms and definitions given in BS 6100-1, BS 6100-6 and BS EN 12670 and the following apply.

3.1 air barrier
layer of the construction that provides the primary resistance to the passage of air through the wall

NOTE The air barrier is typically a part of the backing wall.

3.2 anchors

3.2.1 anchor
fastener which is fixed directly into the stone panel or to a concrete/masonry backing wall

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

3.2.3 undercut anchor
type of expansion anchor that is fitted into a flared or undercut hole

3.3 backing panel
precast concrete panel to which a stone facing is attached

3.4 backing wall
layer of the wall that provides the airtightness and watertightness of a rainscreen system

NOTE The backing wall can be an integral part of the rainscreen system, or it can be part of the building to which a rainscreen is added.

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

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

3.7 bond breaker
material applied to the rear surface of a stone to prevent adherence to a subsequently applied material

3.8 breather layer
layer of a construction that is designed to resist the passage of liquid water from one part of a construction to another, whilst permitting the passage of water vapour in either direction

3.9 bush hammer
percussion tool for roughening a surface, with square head with pyramidal percussion teeth or points

3.10 bush hammering machine
machine consisting of feed rolls and a overhanging beam, supporting a pneumatic hammer

3.11 cavity barrier
construction provided to close a concealed space against penetration of smoke or flame, or provided to restrict the movement of smoke or flame within such a space

3.12 cladding
external covering to a structure

3.13 claw chisel
percussion tool for roughening a surface, with the cutting end covered by several teeth of various size

3.14 dry zone
part of a rainscreen system that can always be assumed to be protected from rainfall, generally on the inside of the watertight layer

3.15 facing
layer of stone attached to a backing panel

3.16 fascia
plain horizontal surface

NOTE A fascia is normally situated over an opening.

3.17 fire stop
barrier that is placed in a cavity to prevent the passage of flame from one part of the cavity to another

NOTE Fire stops are also known as fire cavity barriers.

3.18 fixings

3.18.1 fixing
combination of bracket and fastener/anchors

3.18.2 cladding fixing
device to support or tie back cladding units to the structure

3.18.3 cladding restraint fixing
device to restrain or tie back cladding units to the structure

NOTE The term "tying back fixing" is deprecated.

3.18.4 cleat
small bracket or fixture that is used to connect two parts of a metal framing system together

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

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

3.18.7 fixing bracket
discrete component used as an intermediate connector to join two other components together

NOTE A fixing bracket typically allows for construction tolerances and different orientations of the components to be joined.

3.18.8 grommet
collar around a pin to allow local flexing

3.18.9 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

3.18.10 combined loadbearing restraint fixing
device that transfers the self weight of one or more cladding units to the structure and provides some restraint

3.18.11 pin
stainless steel pin fixed into the stone and into the backing panel

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

3.18.13 stone fixing
fixing device to attach stone facing onto a backing panel

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

3.19 gasket
pre-formed rubber component that is used to seal a joint

3.20 handset cladding
stone panels seated one upon another, supported at defined levels on loadbearing angles and fixed directly to the structure with each stone unit secured with restraint fixings

3.21 joints

3.21.1 baffle
component that is either inserted into the joint or placed immediately behind the joint to prevent the direct passage of water through the joint

NOTE A baffle can be formed by the simple expedient of stepping the panel edges so that they overlap. If it is not possible to see through the joint into the cavity behind then the joint is baffled. A loose fit of the baffle as a separate compartment allows the passage of air.

3.21.2 baffled joint
open joint between two panels, or between a panel and an adjacent element of construction, which contains a simple baffle or other obstruction designed to prevent the direct passage of water through the joint

3.21.3 compression joint
joint designed specifically to accommodate pressure resulting from vertical shortening of the structure relative to the cladding

3.21.4 dry butt joint
joint in which units abut each other without any jointing material

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

3.21.6 horizontal compression joint
joint designed specifically to accommodate partial closure resulting from vertical shortening of the structure relative to the cladding

3.21.7 labyrinth joint
open joint between two panels, or between a panel and an adjacent element of construction, that contains a complex baffle designed to cause several changes of air flow direction

NOTE The construction of the joint prevents the direct passage of water through the joint and also provides changes of direction in order to shed water droplets from the air flow through the joint.

3.21.8 movement joint
joint that permits movement between adjacent parts

3.21.9 narrow joint
joint where the gap between two panels is less than 6 mm, but does not have any added sealing element, relying only on closeness of fit to control the passage of water

3.21.10 open joint
joint between two panels, or between a panel and an adjacent element of construction, not closed by any sealing element, thereby permitting the free passage of air through the joint

3.21.11 sealed joint
joint between two panels, or between a panel and an adjacent element of construction, which is sealed with a gasket, wet-applied sealant or some other material, to prevent the passage of air and water through the joint

3.22 kerf
slot cut into the edge of a panel for the purpose of introducing a fixing device

3.23 mullion
vertical metal framing member used to support a stone panel or panels, or to which transoms are fixed for the purpose of supporting a stone panel or panels

3.24 overcladding
panelled cladding system fixed over an existing wall construction

3.25 pilaster
pier or part of a column attached to a wall

3.26 pointing
cementitious material used to fill a joint between stones

3.27 pressure-equalized rainscreen
rainscreen whereby open joints between the panels are combined with compartmentation of the cavity behind the panels to generate pressure in the cavity

NOTE 1 This reduces the pressure difference across the joints and reduces both the amount of water ingress through those joints and the windload on the cladding panels.

NOTE 2 The initial flow of air through the joints during the pressure equalization process can carry some fine water droplets through the joints, so drainage is needed.

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

3.29 smoke stop
barrier that is placed in a cavity to prevent the passage of smoke from one part of the cavity to another

3.30 soffit
exposed horizontal or sloping (to maximum of 75°) under-surface of any form of construction works

3.31 spigot
component that is inserted into the ends of two hollow sections to align them for the purposes of joining

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

3.33 surfaces/finishes

3.33.1 bush hammered surface
surface obtained by using a bush hammer or a bush hammering machine

3.33.2 filled surface
surface where natural voids in stone are filled with cements, shellac or other material

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

3.33.4 ground surface
surface obtained by means of a grinding or polishing disk, which can be rough, medium, fine, matt or polished

NOTE Different ground surface finishes are obtained by using grinding or polishing discs with varying grain sizes. A rough ground surface can be obtained by using a grain size of, e.g. F 60, a medium ground surface with F 120, a fine ground surface with F 220, a matt ground surface with F 400 and a polished ground surface with a polishing disc or felt.

3.33.5 machine tooled surface
surface finish resulting from a mechanical surface treatment with tools or dressed finish clearly showing tool marks

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

3.33.7 sand blasted finish
matt surface finish resulting from the impact of sand or other abrasive grains expelled by a jet

3.33.8 striated surface
surface obtained by using a claw chisel or a ruling machine

3.33.9 trimmed surface
surface obtained by using pointed chisel and mallet or a grooving machine

3.33.10 water jet streamed finish
matt textured surface finish, accomplished by exposing the surface to a steady jet of water under pressure

3.34 testing

3.34.1 initial type testing
tests undertaken prior to placing a product on the market

3.34.2 production control testing
tests undertaken to determine the consistency of stone during production

3.35 transom
horizontal metal framing member which is used to support a stone panel or panels

NOTE A transom can be supported on mullions or fixed directly to a supporting structure.

3.36 vapour control layer
layer of a construction that is designed to resist the passage of water vapour from one part of the construction to another, in either direction

3.37 ventilated rainscreen
system of cladding in which panels of sheet material are used to shield the majority of a wall from direct rainfall, combined with an air gap (cavity) and drainage system behind the panels

NOTE 1 The drainage system is used to intercept and remove any water which penetrates the rainscreen. Some or all of the joints between the panels are deliberately left open in order to ventilate the cavity.

NOTE 2 The cavity can also incorporate an element of insulation, a vapour control layer and/or a breather layer.

3.37.1 wet zone
part of the rainscreen system that can be assumed to be exposed to rainfall, either directly or as a result of water flowing through joints and gaps in the system

NOTE It is usually possible to identify one layer of the construction as being the watertight layer. All parts of the construction outside this layer can be assumed to be in the wet zone.

4 Exchange of information and time schedules

4.1 General

Information should be exchanged between designers, installers and suppliers to enable the work to be scheduled satisfactorily, an accurate price to be obtained, supply and production difficulties to be minimized and safe and practical site fixing to be achieved.

At the preliminary design stage, the stone(s) selected might still be unquarried, and possibly in a foreign country; consideration should therefore be given to the availability and suitability of the stone(s) and the time for their preparation and delivery to site, especially when large quantities of stone are needed.

4.2 Initial feasibility planning

Information on the following should be obtained at the feasibility planning stage:

a) The total areas to be clad and their locations on the buildings.

b) The aesthetic and/or visual effect needed (referenced to existing buildings) in terms of colour jointing pattern, surface finish, physical characteristics, durability etc. in order to shortlist suitable stones.

c) The natural variations in colour, tone and markings that could occur in the selected stone(s). This should be established during a visit to the quarry.

d) The limitation in face size and thickness of possible stones and their availability from a quarry and/or works.

e) The function of the cladding and the height, location and type of structure to which it is to be fixed

f) The location of fire stops.

A draft project programme should be drawn up showing the time for stone selection, testing regime, order, manufacture and site installation.

NOTE This time might be significant for contracts with large quantities of stone and/or when the supply of stone is from a quarry overseas.

Current performance information of the selected stone should be obtained.

4.3 Tender stage

4.3.1 Design and performance specification

Wherever possible, the following information should be obtained at the tender stage:

a) The building site limitations regarding access, restrictions, the time of deliveries, storage, handling and distribution facilities.

b) Any limitation on the sequence and duration of site fixing, or an invitation to present recommendations.

c) Sufficiently explicit drawings to show the basic construction requirements, stone thicknesses, jointing (including movement joints) and any special stones or labours and the type of surface finish.

d) The building tolerance(s) allowed in the structure, affecting the design width of cavity or overall stone dimensions.

e) The geological name of the type(s) of stone and any demands on matching or selection, or limits on acceptable natural variations referenced back to individual control samples supplied by or viewed at the quarry.

f) The type of jointing and pointing (taking into account the manufacturing tolerances and joint width).

g) The type(s) of sealant to be used.

h) Details of any insulation within cavities and the method to maintain the minimum clear cavity.

i) The fixing system to be used, or design recommendations.

j) Any requirements for the routine or special testing of components, before or after erection, or for sample areas or mock-up panels.

k) The proposed cleaning and maintenance regime (e.g. whether cleaning cradles are to be used).

l) The criteria for the acceptance or rejection of individual stones and fixings.

m) The testing regime and selection of testing samples for the different varieties of stones to be tendered.

4.3.2 Facilities and materials required on site

To prevent misunderstanding, particularly at the tender stage, it should be made clear whether the following will be provided and by whom:

a) A tower, or mobile crane, or forklift for offloading, distributing and raising packed stone adjacent to fixing areas at each level, and elevation.

b) If there is no crane, a suitable hoist to take packed stone, and forklift/pallet truck to place in and take out on to scaffold or structural slab at each level and elevation.

c) A forklift/pallet truck, and level access for the lateral movement of packed stone on to scaffold at each level and elevation, where the hoist cannot be positioned adjacent to working areas.

d) The location of safe storage areas, with firm level access, when stone cannot be directly offloaded and placed adjacent to working areas.

e) The boarded working scaffold (in not more than 2.0 m lifts with three boards between nearest upright and face of cladding, and allowing unimpeded lateral distribution of stone).

f) The props for temporary support of, for example, fascias and soffits.

g) Any adaptation of the scaffold for head trees or step-up brackets.

h) The loading platforms at each level, in number and spacing appropriate to site and performance requirements.

i) The supply of ordinary Portland cement, clean grit sand for bedding and grouting fixings.

j) The supply of any special coloured mix for bedding and pointing.

k) Construction and marking of datum lines and levels at each level, and regularly across elevations.

l) The electrical supply (110 V) and water supply to within 30 m of working areas at each level.

m) The location for the provision of site accommodation/lock-up store, and installation of 240 V electrical supply.

n) The provision of messing, toilet, medical and other welfare facilities.

o) The protection of fixed stone from any likely physical damage or staining.

p) The removal of debris, packing cases etc. from agreed collecting areas.

4.4 Order stage

To enable the installation of stone cladding to be completed within the scheduled time, at the time an order is placed, the parties concerned should be in possession of the following information, or it should be agreed when it will be available:

a) the fixing programme, and sequence, by elevation and levels;

b) a full set of the latest design drawings from the architect and/or structural engineer giving all data relevant to the stone cladding;

c) arrangements for taking site dimensions, if these are necessary;

d) the time for the preparation of working drawings (in fixing sequence when many are involved);

e) the time for the architect to check and return working drawings, either approved, or for amendment;

f) the time between approval of working drawings and first delivery of stone to site;

g) the minimum notice for any changes to the fixing programme, and opportunity to assess cost or extension implications;

h) approved reference stone samples; and

i) limitation on weight and size of boxes/pallets acceptable on sites.

5 Materials and components

5.1 Stones for cladding

5.1.1 General

Common stone types that can be used for cladding fall into the following categories:

a) granite (see **5.1.2**);

b) sandstone (see **5.1.3**);

c) marble (see **5.1.4**);

d) quartzite (see **5.1.5**);

e) slate (see **5.1.5**);

f) limestone (see **5.1.3**);

g) travertine.

For the design of fixings, the density of the particular stone should be ascertained and used.

5.1.2 Granite

Most granites are hard and durable, and retain any finish in an external environment.

5.1.3 Limestone and sandstone

NOTE Indigenous limestone and sandstone are traditionally used naturally bedded.

Typically, limestone and sandstone for cladding in other countries are used face bedded and so imported panels are likely to be face bedded unless specified otherwise; where face bedding is to be used, expert opinion should be sought.

5.1.4 Marble

When marble is used externally, the surface finish should be either honed or eggshell, since polished marble loses its shine in the British climate.

NOTE Polished marble may be used externally where it is accessible for frequent and regular maintenance.

As marble can be prone to bowing and loss of strength, expert opinion should be sought.

5.1.5 Slate and quartzite

Natural markings in slate and quartzite cannot be eliminated, but slate should be assessed in relation to the environmental conditions in which it is to be used. Slate and quartzite with a riven finish have thickness deviations that are unavoidable, but the minimum thickness should not be less than that given in the relevant part of BS 8298.

5.1.6 Finishes to stone faces

It should be specified that surfaces are to have a regular appearance as a function of the finishing process and are to be worked to meet the specified finish (e.g. making reference to samples; see **6.12**) on all exposed faces.

Surfaces should be one of the following finishes:

a) surfaces obtained by grinding:
   1) rough ground surfaces, e.g. by means of a grinding disk of grain size F 60;
   2) medium ground surfaces, e.g. by means of a grinding disk of grain size F 120;
   3) fine ground surfaces, e.g. by means of a grinding disc of grain size F 220;
   4) matt finished surfaces, e.g. by means of a grinding disc with grain size F 400;
   5) highly polished surfaces, e.g. by means of a polishing disc or felt.

b) surfaces obtained by means of hammer-type tools:
   1) bush hammered surfaces;
   2) trimmed surfaces;
   3) striated surfaces.

c) surfaces obtained by other operations:
   1) flamed finished surfaces;
   2) sand blasted finished surfaces;

3) water-jet streamed finished surfaces;
4) machine tooled surfaces;
5) riven finished surfaces.

Finishes to stone faces should conform to BS EN 1469.

5.1.7 Initial type testing

Initial type testing to determine the suitability of stone for use as cladding should be requested in accordance with Table 1.

Testing (other than visual inspections that are carried out at the production facility) should be executed in accordance with the relevant standard and supported by a test report.

Sampling plans should be prepared in accordance with BS EN 1469:2004, Annex A.

Table 1 **Initial type testing of properties/characteristics of slabs for cladding**

Properties/characteristics	Test method
Petrographic description	BS EN 12407
Visual appearance	BS EN 1469:2004, **4.2.3**
Flexural strength	BS EN 13161
Breaking load at dowel hole	BS EN 13364
Water absorption	BS EN 13755
Apparent density and open porosity	BS EN 1936
Frost resistance	BS EN 12371

NOTE In order to provide sufficient data to allow the panel performance to be assessed, the breaking load at the dowel hole might need to be determined for more than one specimen thickness.

5.1.8 Factory production control testing

Factory production control (FPC) testing should be requested for all stone for use as cladding in accordance with the test method and frequency as given in Table 2.

NOTE When the tests previously carried out on rough blocks or semi-finished material are relevant for the cladding panels, the supplier might refer to them.

Table 2 **FPC testing of characteristics of slabs for cladding**

Characteristics	Test method	Control frequency
Geometrical characteristics	BS EN 13373	Every production lot
Visual appearance	BS EN 1469:2004, **4.2.3**	
Flexural strength	BS EN 13161	In accordance with the FPC 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 FPC system but at least every 10 years
Breaking load at dowel hole	BS EN 13364	
Frost resistance	BS EN 12371	

5.1.9 Provision of test data for a specific project

NOTE A specific project might require testing in addition to that required by BS EN 1469. However, in a project where the stones have a good previous history of use in similar circumstances and recent test data are available, there might be no requirement for additional testing.

Where additional testing is required, the guidance given in Table 3 should be followed.

Table 3 **Stone testing regime in addition to the requirements of BS EN 1469**

Conformance	**Good history of use in similar locations**	**Little previous history of use in similar locations**
Conforms/all test data satisfactory	Test regime 1	Test regime 2
Does not conform/some test data unsatisfactory or marginal	Test regime 2	Test regime 3

Test regime 1: Limited testing to verify that the current production is consistent with past results, e.g. density and porosity, water absorption, flexural strength of specimens at "project" thickness.

Test regime 2: Limited testing as in test regime 1 but with additional testing of particular areas of concern, e.g. strength test for a novel fixing system or freeze/thaw tests, and other relevant durability tests if in a susceptible location.

Test regime 3: Extensive additional testing and FPC testing, including a complete initial type test in accordance with BS EN 1469 and regular FPC 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, and other relevant durability tests if in a susceptible location).

5.2 Fixings

NOTE This subclause refers to alloys readily available in the UK. This does not preclude the use of other alloys if their suitability can be demonstrated.

5.2.1 Stainless steel fixings

NOTE Stainless steel is the name give to a group of corrosion-resistant alloys that contain varying percentages of chromium and nickel. The group includes austenitic, martensitic, ferritic, duplex and super duplex alloys. It is only the austenitic range of alloys that are currently used for the manufacture of fixings for cladding.

All stainless steel fixings selected for use, i.e. cramps, ties, angles and other fabrications, should be of austenitic stainless steel sheet, strip and plate conforming to BS EN 10088-2, and stainless steel rod and bar conforming to BS EN 10088-3.

The grade of stainless steel should be selected in accordance with its application, as given in Table 4 taking into account the working stresses required, the location of the building and level of exposure.

It is essential that welding is undertaken only where the necessary facilities, expert knowledge, inspection and testing facilities and skills are available. Scaling and discoloration caused by welding, hot working and heat treatment operations should be removed by suitable cleaning methods in order to maintain the intrinsic corrosion resistance of the material. Advice should be obtained from the steel supplier/manufacturer.

NOTE 1 Such cleaning might not be essential for all fixings but if scale is not removed, premature rust staining of the surface is likely to occur, corrosive attack can commence more readily and a shorter serviceable life can result.

NOTE 2 Rust staining of the surface can occur as a result of surface contamination, which arises from particles of non-stainless steel tools used in the manufacture of the fixing component. Although such rusting is unsightly, it generally has no long-term detrimental effects on the performance of the fixing.

Table 4 **Stainless steel grades and application**

Steel grade (designation given in accordance with BS EN 10088-1)		**Formerly known as** [A)]	**Application**
Name	**Number**		
X5CrNi18-10	1.4301	304 S15 304 S16	For general fixings
X46CrS13	1.4035	303 S31	For fixings that need significant machining (i.e. cast-in sockets). It is not suitable for welding or working on-site
X2CrNi18-9	1.4307	304 S31	For hot working or welding
X5CrNiMo17-12-2	1.4401	316 S31	For enhanced resistance to pitting corrosion (e.g. for use on coastal sites)
X2CrNiMo17-12-2	1.4404	316 S11	For hot working or welding for use on coastal sites
X2CrNiMo18-14-3	1.4435	316 S16	For hot working or welding for use on coastal sites
X6CrNiTi18-10	1.4541	321 S31	For the welding of heavy plate 20 mm thick and above where great heat might be generated

[A)] For historical clarification, the steel grade with designation given in accordance with BS 970-1:1991 (withdrawn) and BS 1449-2:1983+A4 (withdrawn) has been provided.

5.2.2 Stainless steel bolts and nuts

Bolts and nuts selected for use should be of stainless steel grade A1, A2 or A4, with the grade of the stainless steel stamped on the head of the bolt or face of the nut, e.g. A2 50 for a bolt of grade A2 with an ultimate tensile strength of 500 N/mm^2.

NOTE 1 The grade of bolts and nuts selected are identified as:

a) A1, which generally equates to 1.4305;

b) A2, which generally equates to 1.4301; or

c) A4, which generally equates to 1.4401.

NOTE 2 The grade reference allows confirmation that the correct bolt and nut is being used. This is particularly important in highly loaded and critical fixings.

5.2.3 Non-metallic components

Where non-metallic components, e.g. resins, plastic and nylon plugs, are to be used, their performance and life expectancy should be taken into account.

5.3 Materials for mortar

5.3.1 Cement

Ordinary and rapid hardening Portland cement should conform to BS EN 197-1. Masonry cement should conform to BS EN 413-1.

5.3.2 Lime

Lime should conform to BS EN 459-1.

5.3.3 Plaster

Plaster should be class A plaster of Paris as specified in BS EN 13279-1.

5.3.4 Sands

Sands from natural sources should conform to BS EN 13139.

5.3.5 Admixtures and pigments

5.3.5.1 General

Admixtures can affect the strength and adhesion of mortars and should be used with care.

5.3.5.2 Calcium chloride

Calcium chloride and admixtures containing calcium chloride should not be added to mortars.

5.3.5.3 Plasticizers

Mortar plasticizers should conform to BS EN 934-3.

5.3.5.4 Pigments

Pigments should conform to BS EN 12878.

5.3.6 Water

Water should be from the public mains or other potable supply. If mains water is not available, the water should be clean and should not contain any material, either in solution or in suspension, in quantity sufficient to have a harmful effect on the mortar or stone, or on metals or to impair the durability of the construction.

In cases where water supplies might be of doubtful quality, the methods used for sampling and testing the water should be in accordance with BS EN 1008.

5.3.7 Ready-to-use mortars and ready-mixed lime:sand

Ready-mixed lime:sand for mortar and ready-to-use retarded cement:lime:sand and retarded cement:sand mortars should conform to BS EN 998-1. Dry-packaged cementitious mixes should conform to BS EN 998-1.

NOTE When ready-mixed mortars are used, it is important that the sand and aggregate have the correct grading sizes.

5.4 Damp-proof courses, flashings, weatherings and cavity trays

5.4.1 General

Damp-proof courses, flashings, weathering and cavity trays should conform to the recommendations and relevant British Standards given in Table 5 and Table 6.

Only durable materials that do not stain stones should be used.

Table 5 **Damp-proof courses**

Material	Standard and grade	Minimum thickness mm	Other recommendations
Lead	BS EN 12588:2006, code no. 3	1.32	Protection against contact with mortar and concrete by a coating of bituminous paint should be provided.
Bitumen	BS 6398	As classified in BS 6398	—
Polyethylene	BS 6515	0.46	—

Table 6 **Flashings, weatherings and cavity trays**

Material	Standard and grade	Thickness mm	Other recommendations
Aluminium alloy	BS EN 485-1:2008+A1, BS EN 485-2:2008, grade 3103	0.6 to 0.9	Prefabricated items should be of H2 or H4 temper; items worked on-site, “0” condition.
Aluminium	BS EN 485-1:2008+A1, BS EN 485-2:2008, grades 1050A, 1050A and 1200	0.6 to 0.9	These items should be protected against mortar contact by a bituminous compound.
Lead	BS EN 12588:2006, code nos. 4 and 5	1.8 to 2.24	Lengths should not exceed 1.5 m.

5.4.2 Metals

Sheet metal for flashings and weatherings should be selected after consideration of the conditions of use, exposure and chemical action due to contact with other materials. Aluminium, zinc and their alloys, when in contact with certain other metals in the presence of moisture, can suffer bimetallic corrosion, and their direct contact with other metals used in cladding (especially copper or copper alloys) should be avoided. Where such contacts are unavoidable, it is essential that precautions are taken to insulate dissimilar metals from bimetallic corrosion (see **5.7**).

Copper should not be used for flashings or weatherings (and is unlikely to be used as a damp-proof course). If it is used, rainwater running off copper or copper alloy flashings should not be allowed to come into contact with flashings or components made of aluminium, zinc or their alloys, unless the latter can be protected with a coating of bitumen or other suitable material.

Where initial white carbonate run-off from lead flashings could stain the stones below, a smear coat of patination oil after fixing should be applied.

5.4.3 Other materials

Materials other than metals can be used for flashings, but the use of such materials should be carefully considered as the life of some depends largely upon the extent of direct exposure to the weather.

Some materials, such as mineral fibre reinforced bitumen, need to be heat softened to shape, while others, such as polyethylene or bitumen polyethylene, are held in position by an adhesive selected for the particular material. The choice of any materials for flashings should take these points into consideration at the design stage, bearing in mind the methods of construction of the building.

Although bitumen-based materials can be used for damp-proof courses, they should not be considered suitable for other purposes.

5.4.4 Location and joints

Where damp-proof courses and cavity trays are incorporated in the bed joint, the joint should be of sufficient width to allow the damp-proof course or cavity tray to have a mortar bed above and below in accordance with the manufacturer's guidance and should be able to accommodate the thickness of the damp-proof course material, even where this is lapped.

NOTE It is unlikely that the joint width will be less than 10 mm.

The damp-proof course or cavity tray can finish flush with the stone, but it is recommended that it projects beyond the face of the cladding by 5 mm.

A damp-proof course or cavity tray should always be located below porous or jointed sills or thresholds. Where the sills and thresholds are one piece and built in, they should have their bed joints temporarily left open except under the end bearings, to prevent fracture in the event of settlement. Where this compromises the performance of the damp-proof course, its location should be altered or the type of damp-proof course changed.

5.5 Sealants

General guidance on the choice of sealants is given in Table 7 and in BS 6213; however, as the subject is complex, further guidance should be sought from the manufacturers or their technical literature.

NOTE 1 Advice is also available in CIRIA's Manual of good practice in sealant application [1].

Plasticizers used in some sealants can cause staining of the stone and reference should be made to the sealant manufacturer to confirm their suitability and fitness for purpose in the proposed application. In the case of a stone with unknown properties, stain testing should be carried out with the proposed sealant material.

NOTE 2 Many sealants require primers.

Table 7 **Sealants**

Sealant	Granite, slate, quartzite	Marble, limestone sandstone	Movement in service
Acrylic resin (solvent type)	C	C	Low to medium
1 part polysulfide to BS EN ISO 11600	R	R	Medium
1 part polyurethane	R	R	Medium to high
Silicone type A (low modulus) to BS EN ISO 11600	C	C	High
2 part polysulfide to BS EN ISO 11600	R	R	High
2 part polysulfide (high modulus)	C	C	Medium
2 part polyurethane	R	R	High

R = Recommended

C = Confirm suitability with manufacturer

NOTE The expected service life of the sealants listed might be limited to 20 years, but depends upon environmental conditions and quality of application. See BS 6093 and BS 6213 for further information on the selection of construction sealants.

5.6 Back-up materials

*COMMENTARY ON **5.6***
In addition to performing a bond breaker function, back-up material can also be used to control the sealant depth in a joint and to provide a compressible space into which the sealant can deform under compression, resulting from joint closure.

All back-up materials should be installed in the joint under a degree of compression.

The selection of a suitable back-up material should take into consideration:

a) foam density: should be sufficient to provide support during application of the sealant;

b) compression loading: should not be too high, so that significant load transfer can occur during joint enclosure;

c) environmental resistance: should be resistant to the conditions of water, chemical or solvent contact;

d) cellular structure: should be such that it does not cause wicking or absorption of water, usually specified as closed cell foams.

NOTE Back-up materials are commonly of polyethylene or polyurethane, but synthetic rubber types are available. They can be obtained in sheet, square, rectangular or circular section strips. The circular section is preferred since it can be more easily inserted, is not subject to twisting displacement and provides a suitable shape to the sealant.

5.7 Bimetallic corrosion

Contacts between electrochemically dissimilar metals should be avoided. If the use of dissimilar metals cannot be avoided, e.g. where facing units are to be attached via bolted connections to structural steel members, the fixing should be isolated with bushes and washers of materials such as nylon, neoprene, polytetrafluoroethylene (PTFE) or synthetic resin bonded fibre (SRBF). Paint coatings should not be used as they are unlikely to provide adequate isolation, especially for structural connections. Where it is not possible to isolate dissimilar metals and a metallic contact could be possible at the joint, professional advice should be sought.

The type of isolator selected should be dictated by:

a) the type of fixing being used;

b) the location/exposure both on building and in relation the environment;

c) the nature of the applied loading; and

d) the life expectancy for the structure/component.

The environment in which the contact occurs should be carefully considered when assessing the potential problems with metallic contact, i.e. whether it is likely to be continuously dry (e.g. behind the vapour blanket), wetted frequently or immersed. If the exposure conditions are other than industrial/urban, guidance should be sought from either PD 6484 or a professional in this field.

NOTE 1 Table 8 is only for metals being used in an industrial/urban atmospheric environment. The table indicates when additional corrosion can be expected: there is no indication regarding the rate of corrosion with or without the bimetallic connection. It does not cover materials in atmospheric marine, or immersed exposure conditions. Some of these combinations might, however, be possible in a rural environment.

NOTE 2 Metals commonly used in buildings include:

- *stainless steel, either structural components or sheet;*
- *structural steels (which may be carbon or low alloy steels);*
- *zinc either as a protective coating on the steel or possibly as small die cast fittings;*
- *aluminium as extrusions for framing or sheet for panels;*
- *cast iron normally as columns; and*
- *lead as sheet for roofing.*

Table 8 **Metals under consideration in an industrial/urban atmospheric environment**

Primary consideration	**Secondary considerations**					
	Stainless steel (austenitic)	**Structural steel**	**Zinc**	**Aluminium**	**Cast iron**	**Lead**
Stainless steel (austenitic)	—	0	0	0	✘	✘
Structural steel	✘	—	0	0	✘	✘
Zinc	✘	✘	—	✘	✘	✘
Aluminium	✘	✘	0	—	✘	0
Cast iron	✘	0	0	0	—	✘
Lead	0	0	0	0	0	—

Key

0 = is unlikely to suffer additional corrosion

✘ = should not be used together without isolators

NOTE The metals shown in the left hand column (i.e. the primary consideration) are those that could suffer additional corrosion as a result of the metallic contact with the other metal (i.e. the secondary consideration).

6 Design

6.1 General

In the case of projects involving the extensive use of cladding and fixings, it is recommended that the structural engineer/designer sets down the functional requirements governing the principles of its design, its means of support and restraint, and the maximum movement of the cladding for which allowance is to be made, together with the anticipated movement characteristics of the building frame, including calculations of the anticipated shortening and how this is to be accommodated in the cladding (see **6.13**).

On such projects, it is further recommended that a technical specification dealing with all aspects of the supply and/or fixing of the cladding is prepared in consultation with appropriate specialists and that this includes definitions of the nature of any special tests required to be carried out on the cladding in advance of the work. Accuracy in the construction of the background structure is essential; otherwise the fixings designed for the job might not fit.

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

6.2 Cavities

It is essential to provide a cavity between the cladding and the structure to allow:

a) accommodation of fixings, bolt heads and blockliners that could add up to 25 mm or more;

b) permitted tolerances in sawing thicknesses, erection and structural face lines;

c) accommodation of insulation, if required (see **6.4**);

d) discontinuity to minimize the transmission of rainwater;

e) free draining of any trapped moisture between the stone cladding and the background.

The width of the cavity should be designed to leave a clear gap not less than 10 mm wide after all construction tolerances have been accommodated.

It is essential that weep holes are provided at points where any entrapped moisture could accumulate, e.g. at cavity trays and at damp-proof course levels.

When a cavity wider than 100 mm is necessary, a supplementary framework or special fixing should be provided to support and restrain the cladding. Extended fixings capable of resisting the additional horizontal buckling loads, which limit deflection from any dead loads to ≤ 1 mm, should be used.

6.3 Cavity barriers to resist spread of fire

It is essential that the cladding design includes cavity barriers to prevent the spread of fire, both horizontally and vertically, in the cavity behind the units; and to reduce the effect of fire on fixings. Horizontal cavity barriers should be located at each storey to prevent the spread of fire from storey to storey. Vertical cavity barriers should abut compartment walls. Particular care should be taken with the detailing of cavity barriers at fixings and at vertical joints between units in order to avoid gaps in the cavity barriers.

NOTE 1 Experience has shown that fires can spread at these points.

Cavity barriers should be composed of non-combustible materials having at least 30 min fire resistance. They should be adequately fixed and supported to ensure that they remain effective for the life of the cladding.

NOTE 2 Attention is drawn to the Building Regulations [2–4] which require that cavities and concealed spaces in the structure or fabric of a building are sub-divided or sealed by means of cavity barriers or fire-stopping to restrict the hidden spread of smoke and flame.

6.4 Insulation behind cladding

In situations where it is necessary to provide insulation behind the cladding, such insulation should be:

a) non-combustible or of limited combustibility;

NOTE 1 Attention is drawn to the Building Regulations [2–4].

b) non-absorbent;

c) rot and vermin proof.

The insulation should be fixed in such a manner as to maintain a clear cavity behind the stone cladding (see **6.2**).

NOTE 2 Some insulating materials need a residual air gap for waterproofing purposes. Some stones might be adversely affected if they are not allowed to dry out.

Where the insulation material is cut out to accommodate fixings it should be replaced. The insulation material selected should be easily cut and capable of being re-fitted to provide continuity of the insulation.

6.5 Weathering and water run-off

Likely changes in colour and texture of the stone on exposure to the weather should be considered, so that these changes can be anticipated either in the design or in the selection of the material for the cladding. Possible changes in the colour of the jointing materials should also be taken into account.

*NOTE The changes in appearance of the façade of a building exposed to the weather are mainly influenced by the aspect and location of the building, the design of the cladding, particularly in relation to the run-off of rainwater, the degree of atmospheric pollution (see **6.6**) and the effect of frost action (see **6.7**).*

Conspicuous disfigurement can be caused by uneven washing of cladding by rainwater, particularly where cladding is used in association with glazed areas. The use of textured surfaces should be considered as they help to distribute the flow of water more evenly and projections on the façade can be designed to throw the water clear. Projections should not contribute to uneven washing.

Overhangs to sills, cornices and string courses should incorporate the correct fall to the top surface and a throat (a groove in the under surface designed to prevent water running back across it).

Disfigurement of plinths can be caused by moisture absorbed from the backing structure, rising damp and rainwater splashing from pavements and earth. This should be minimized by the careful design and incorporation of damp-proof courses or the use of durable and possibly dark stones.

Whichever way the cladding is constructed and jointed, it should be anticipated that it will permit some rainwater penetration and/or condensation within the cavity between the cladding and the inner leaf or back-up wall. Consideration should always be given to applying a damp-proof course membrane to the outer face of the inner wall. Cavities should therefore have adequate provision for drainage and for damp-proofing. The possibility of rainwater running off and cleaning or staining the façade below should be considered at the design stage.

6.6 Atmospheric pollution

The rate at which units become dirty as a result of atmospheric pollution in any particular locality should be ascertained by examination of other buildings in the district, particularly noting the factors that have determined the degree of disfigurement.

6.7 Frost action

Where there is a potential for frost damage, measures should be taken to provide reasonable protection. With certain stones, including the softer limestones, the use of thin open joint construction is not recommended. Instead, for these stones, the use of lead flashings on cornices, strings or other projecting courses is recommended in order to avoid saturation on horizontal surfaces and subsequent frost damage.

6.8 Salt crystallization

Where there is a potential for salt damage (e.g. plinth courses, salt spray), materials with proven durability should be used.

6.9 Efflorescence

NOTE Efflorescence is a white coating caused by the migration in solution of soluble salts present in some building materials to the surface, where they crystallize. It is not usually troublesome on cladding, unless the cladding is located against salt-bearing brickwork.

Efflorescence should be left to weather normally.

6.10 Staining

To avoid the possibility of the face of the cladding becoming stained by the corrosion of metals, non-staining materials, such as stainless steel, should be used.

Advice on the selection of timber species and finishes should be sought from the relevant trade associations.

NOTE 1 Certain timbers contain water-soluble extractives that can discolour all types of stone. Similarly, some exterior wood finishes are susceptible to chalking, which can also discolour stone.

Plasticizers used in some sealants can cause staining of the stone and reference should be made to the sealant manufacturer's instructions to confirm their suitability for the proposed application.

NOTE 2 Many sealants require a primer.

6.11 Choice of stone

COMMENTARY ON ***6.11***
Stone is liable to vertical and horizontal variation within its mass; where beds are of sufficiently regular character and the stone has a proven historical performance, 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. In some beds, blocks of good or inferior quality can be distinguished by inspection; in others, the differences are not readily apparent and expert opinion needs to be obtained.

At the design concept stage of a project, a stone shortlist should be prepared based on colour, texture, suitability, availability and cost. The shortlist should be reduced at the tender stage to one or two stones that have been thoroughly researched to establish that:

a) adequate quantities of block, allowing for manufacturing wastage, are available from the quarry to meet the construction programme;

b) an acceptable and agreed range of aesthetic and geological features that has been clearly documented is feasible;

c) the largest and most frequently occurring project unit sizes can be readily produced from blocks available from the selected quarry bed;

d) historical tests, reference buildings and, where appropriate, approval tests (in accordance with BS EN 1469), demonstrate that the stone is suitable for the proposed application.

It is important that the overall project programme takes into consideration all the factors that could affect stone quarrying, design, manufacture and installation.

It is essential that the stone finally selected is sound, durable and suitable for its intended use. The designer should be satisfied that adequate factory production quality control measures are in place to ensure that all finished stones are free from vents, cracks, large fissures, sand and clay holes and other defects likely to affect durability or structural integrity.

Some surface finishing processes (e.g. flamed finish) can cause significant disruption to depth with associated reduction in strength and expert opinion should be sought.

6.12 Stone samples

NOTE Annex A provides guidance on the implementation of a sampling plan, sampling reports and sampling regime.

6.12.1 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 production 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 about 150 mm × 150 mm. They cannot show the natural variations in visual appearance, colour, texture and geological features that are present in all natural stones. Control samples need to be supplied and agreed for this purpose. The labelling of all samples will generally be in accordance with BS EN 12440 and BS EN 12670, i.e. traditional trade name, geological origin and petrological family. It is important that the surface finish and grit size used are clearly stated to allow the specifier to accurately specify the stone.

6.12.2 Control stone samples

Control stone 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.

The control stone samples should be large enough to give the designer a clear indication of the aesthetic characteristic of the stone: either 1 000 mm × 500 mm or at least the size of the panels to be used on the project. The number of control stone samples should be sufficient to show the range of the geological characteristics of the stone.

NOTE Typically, nine panels are sufficient.

The control stone samples should be viewed by the designer and the assistance of a qualified experienced geologist is recommended.

Once approved, the samples should be distributed for use during factory production quality control at the quarry and masonry factory. Any duplicate control stone samples should be approved by the designer before despatch. All approved samples should be photographed and recorded.

6.13 Accommodation of dimensional changes

NOTE 1 Dimensional changes might result from a variety of claddings.

Table 9 summarizes the origins of movement in various types of structures and should be used to assess possible building movements.

Table 9 **Origins of movement in structures**

Type of structure	**Source of movement**						
	Elastic deformation	**Thermal movement**	**Differential settlement**	**Drying shrinkage**	**Moisture movement**	**Creep**	**Long-term expansion**
Steel framed	✓	✓	✓	✘	✘	✘	✘
Concrete framed	✓	✓	✓	✓	✓	✓	✘
Concrete and calcium silicate masonry	✓	✓	✓	✓	✓	✓	✘
Fired clay masonry	✓	✓	✓	✘	✓	✓	✓

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 units. These movements should be accommodated to avoid substantial stresses being imposed on rigidly fixed units, 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.

The design of fixings should 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 for 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.

6.14 Impact resistance

*COMMENTARY ON **6.14***
All exposed building surfaces are liable to impact, whether accidental (slips and trips) or deliberate (vandalism, stone throwing). Impacts can be loosely classified into two types: soft body and hard body.

Soft body impacts are generally associated with persons falling against the surface (typically within 1.5 m of floor level), or with contact by cushioned access equipment (often at higher levels, e.g. during routine maintenance or cleaning). The impact body is generally heavy, but there is sufficient flexibility in the impacting body to absorb some of the impact energy and reduce the shock loading.

Hard body impacts are associated with smaller lighter objects that have less mass but might have hard corners or protrusions, e.g. tools or stones, being thrown against or dropped on a surface. 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 considered in this part of BS 8298. If an area is prone to vandalism in the form of thrown objects, thin natural stone cladding is not a suitable choice of façade system, unless steps are taken to discourage such activities, by the use of barriers, security patrols or closed-circuit television systems. Tools used at height need to be secured so that they cannot fall, thus accidental impacts due to tools being dropped should not occur to a vertical surface. Access equipment which can come into contact with the façade needs to be provided with suitable padding or cushioning to prevent hard contact from occurring.

Impact has two potential consequences: loss of performance (serviceability) and safety hazard (safety). The panels in a stone cladding system, however, do not generally affect the performance other than with regard to weathertightness, and the backing wall needs to be weathertight even if one of the panels is broken or missing.

*Serviceability impact testing is not therefore considered in this part of BS 8298, and the recommendations in **6.14.1** are applicable only to soft body impact testing for the purpose of demonstrating safety in use.*

6.14.1 Risk of impact

6.14.1.1 General

The risk of impact on the surface of the ventilated rainscreen system should be classified in accordance with Table 10.

Table 10 **Impact risks**

Category	Description and example
A	Parts of the wall within 1.5 m of floor level and where pedestrians might brush against or touch the wall, in areas readily accessible to the public and others with little incentive to exercise care, in areas prone to vandalism and/or abnormally rough use. Includes walls of buildings adjacent to pavements or other thoroughfares, or adjacent to other public areas accessible at night.
B	Parts of the wall within 1.5 m of floor level and where pedestrians might brush against or touch the wall, in areas readily accessible to the public and others with little incentive to exercise care, in areas where there is an increased chance of an accident occurring or of misuse. Includes walls of buildings adjacent to pavements or other thoroughfares, or adjacent to other public areas accessible at night, but where there might be security patrols or CCTV systems.
C	Parts of the wall within 1.5 m of floor level but only where accessible to persons with some incentive to exercise care, in areas where there is some chance of an accident occurring or of misuse. Includes walls of buildings adjacent to private areas, balconies or where there is a barrier to prevent public access.
D	Parts of the wall within 1.5 m of floor level but only accessible to persons with high incentive to exercise care, in areas where there is a small chance of an accident occurring or of misuse. Includes areas that are fenced off, or where a permit to work would be required.
E	Parts of the wall more than 1.5 m but only up to 6 m above floor level, typically out of reach of direct human impact but within range of thrown objects or in a zone where a ladder or other access equipment might be used.
F	Parts of the wall more than 6 m above floor level, where access equipment might be used.

6.14.1.2 Impact performance

Once the impact risk has been classified, the level(s) of impact performance to be achieved during testing should be determined in accordance with Table 11. Soft body impact testing in accordance with BS EN 12600 should then be specified, with classification in accordance with BS EN 14019.

If the building is in an area where vandalism is a particular concern, this should be taken into account by either considering the use of lighting and security cameras to deter vandals, or using a more resilient wall finish.

Table 11 **Levels of impact performance**

Category	Impact performance level (BS EN 14019)	Drop height during testing mm
A	None applicable; seek other means to reduce risk of damage	—
B	E4	700
C	E4	700
D	E4	700
E	E3	450
F	E2	300

6.14.2 Improving soft body impact resistance

Generally, the best impact resistance is achieved by using a thicker panel (lower bending stresses, greater thickness of stone over fixings), with shorter spans (lower bending stresses); more flexible fixings (energy absorbed by deformation of fixing or material around fixing); or a more flexible support frame or backing wall (energy absorbed by deformation of supporting structure).

The following factors should be taken into account as they influence the impact resistance of a stone panel for a given thickness and type of stone:

a) the span of the panel between fixing points;

NOTE 1 A larger span means that the stone is more flexible and bends more, transmitting less force to the fixing points. This is more likely to lead to a type A failure.

b) the distance from the corner of the panel to the fixing point;

NOTE 2 If the fixing is further from the corner, an impact near the corner is more likely to cause a type B failure, due to high bending stresses in the stone at the point of fixing. These bending stresses are magnified by the machining or drilling of the stone to accommodate the fixing.

c) the thickness of stone between the fixing and the front face of the stone;

NOTE 3 Forces which are transmitted to the fixings are primarily resisted by the thin layer of stone between the face of the stone and the fixing. A fixing which is nearer to the face of the stone is weaker.

d) the degree of cutting to accommodate the fixing;

NOTE 4 Cutting, drilling or machining of the stone in order to accommodate the material both reduces the thickness of material that absorbs loads and generates stress concentrations. As the degree of cutting or machining increases, the risk of a type C failure or a type B failure initiating at a fixing point increases.

e) the presence of resilient material between the fixing and the stone;

NOTE 5 If the fixing is isolated from the stone by a material that is able to absorb some energy through compression, such as a rubber or sealant material, this reduces the localized stresses in the stone at the point of fixing, and reduce the likelihood of a type B or type C failure.

f) stiffness of the support brackets;

NOTE 6 If the support brackets are overdesigned, they are less able to deflect under an applied load, and this increases the proportion of the energy which can be absorbed by the stone itself.

g) stiffness of the backing wall or support framework;

NOTE 7 If the backing wall or support framework is able to deflect, it absorbs some of the impact energy and reduces the probability of the stone breaking. If the backing wall or support framework is too flexible, it can cause the stone panels to break as the framework rebounds from the impact.

h) edge working.

NOTE 8 Working of the edge of the panel, e.g. with a rebated edge or a continuous kerf to accommodate fixing, reduces the strength of the edge of the panel, thereby increasing the probability of breakage due to excessive bending stresses.

If greater spans are necessary, it is possible to place pads or a stiffening structure behind the panel. If pads are used behind the stone panel, these should have a layer of resilient material between the pad and the stone to prevent hard contact of stone against metal.

The worst locations for accidental impact are within 1.5 m of the floor so thicker stone or a different type of cladding should be considered for these locations if impact resistance is a particular concern.

7 Workmanship in production

7.1 General

It should be specified that:

a) the material is to be selected from the quarry specified and to be equal to the approved sample or fall within the approved range of samples;

b) any special shaping of exposed faces is to be accurately worked before delivery to site other than in those exceptional circumstances where this can only be carried out on-site; and

c) where fine work or polished finish is necessary, particular care is to be taken to prevent chipping or damage to arrises or faces.

7.2 Sizes

7.2.1 General

It should be specified that the units are to be worked to sizes indicated on the approval drawings and within the permissible deviations (see **7.2.2**).

7.2.2 Permissible deviations for cladding

The following tolerances should be specified for cladding:

a) face length and width: in accordance with Table 12;

b) thickness: in accordance with Table 13;

c) bow or twist: ±1.5 mm in 1 200 mm for all finishes other than natural riven faces, and ±10 mm in 1 200 mm for natural riven faces;

d) flatness of the surface: ±2% of the slab length or ±3 mm, whichever is less, for all faces other than natural cleft faces, and as declared by the manufacturer for natural cleft faces; and

e) squareness/length of diagonals: ±0.5% of the nominal dimension or ±5 mm, whichever is less.

Table 12 **Tolerances on length and width of face dimensions**

Sawn edges thickness	**Tolerance** mm	
	Nominal length or width ≤ 600 mm	**Nominal length or width > 600 mm**
≤ 50 mm	±1	±1.5
> 50 mm	±2	±3

NOTE Stricter tolerances may be declared by the manufacturer. This is particularly important when the edges of the slabs are to be visible.

Table 13 **Tolerances on thicknesses**

Nominal thickness (*t*) mm	**Tolerance** mm
12 < t ≤ 30	±2
30 < t ≤ 80	±3
> 80	±5

7.2.3 Permissible deviations for masonry units (sills, copings, string courses)

The following tolerances should be specified for masonry units:

a) length: ±3 mm;

b) section: ±2 mm of the template or profile. Adjacent stone needs to match more closely; and

c) squareness/length of diagonals: ±0.5% of the nominal dimension or ±5 mm, whichever is less.

7.3 Mortices

It should be specified that the mortices, sinkings, perforations and notches for cramps, dowels and corbel plates for supporting nibs are to be:

a) carefully formed, prior to delivery to site, using machinery and tools that prevent cracks in the stone resulting from the process;

b) carefully positioned to ensure alignment of adjacent stones, in accordance with drawings and where possible prior to delivery to site; and

c) in accordance with Table 14 for location, depth and diameter (shape).

Where mortices, sinkings, perforations and notches have to be formed on-site, the work should only be carried out by a qualified mason using the appropriate equipment.

Table 14 **Tolerances for the shape of dowel holes**

Dimension	**Tolerance** mm
Location measured along the length or width of the slab	±2
Location measured across thickness (to be measured from the exposed face)	±1
Depth	$^{+3}_{-1}$
Diameter	$^{+1}_{-0.5}$

Where closer tolerances are required, e.g. when 3 mm wide joints are specified, these should be agreed between the specifier and supplier.

7.4 Marking

It should be specified that each unit is to be clearly marked with an identification symbol that identifies its position on the building.

7.5 Production and storage

Production and storage of units should be arranged so that delivery in accurate sequence for site fixing is possible. Where undercover storage of finished units is not possible, it is essential that protection against frost and staining is provided.

8 Workmanship on site

8.1 General

Safe and adequate access should be provided to and about the working area.

Temporary supports, jointing and bedding materials, fixings and tools should be pre-positioned at the fixing point. All temporary wedges, shims, spacers and other devices not designed for permanent inclusion in the structure should be removed and the spaces made good, as necessary.

8.2 Supervision

The use and positioning of fixing components, whether in the structure before the application of the cladding or in the cladding, and the formation of movement and compression joints should be carefully supervised at all times.

8.3 Fixings

Close liaison between all parties should be maintained so that the type and number of fixings used in the cladding are in accordance with the approved production drawings. Any approved variations should be recorded.

8.4 Joints

The condition of the edges of the units should be examined, especially if they are liable to have a dusty surface which would impair the bond between the jointing material and the unit, if not cleaned.

It is essential that the application of sealants is carried out in accordance with the manufacturer's instructions and that any sealant material is not used after the manufacturer's stipulated time (see **8.9.3**).

Particular attention should be paid to compression and movement joints to see that they are kept free of any material that is not compressible (see **9.2**).

Where mortar is mixed on-site, it should be prepared using a gauge box, bucket or similar container, to the mix proportion specified. The sand or crushed stone dust used should be of the correct grading for the joint width.

Where mortar joints are being used, the stone cladding may be bedded and pointed with the same mortar as work proceeds.

Where the stones are being set on shims and pointed once erection is complete, the pointing should penetrate to a depth of at least 25 mm for stone cladding 75 mm thick. For thinner cladding, the pointing should penetrate to at least half the thickness of the stone.

Where the cladding panels are set on shims, under no circumstances should these be left in position unless the material from which they are made is durable and stable and their size is such that they do not impose undue stress on the stone.

Where temporary shims are used, they should be removed once the mortar has achieved sufficient strength and before additional load is imposed.

8.5 Scaffolding

The scaffold structure should conform to BS EN 12811-1. In order to allow space for the erection of the cladding, the scaffold should be in 2 m lifts. In the case of an independent tied scaffold, which has two lines of standards, the inner line should be at least one board clear of the finished face of the cladding with extended transoms, or hop up brackets to carry an inside board. Diagonal braces should not prevent the stone being moved along scaffold runs.

NOTE For some work it might be necessary to provide holes or slots in the cladding for scaffold fixings. Purpose made stone plugs may be resin fixed in afterwards as the scaffolding is removed.

A drawing of the position of stone plugs should be available so that the holes or slots can be re-used for later maintenance. Non-corroding metal or alloy should be used for scaffold fixing points.

8.6 Temporary head trees

Temporary head trees should be adequate for the loads to be sustained and should be securely but temporarily fixed and capable of being easily removed. They should be rigid and independent of movement of the scaffold.

Where the supports are of timber or metal, backing and polyethylene sheeting or other non-staining protective material should be used to protect any units on which they rest from staining and damage.

8.7 Building attachments, including signage

Signs and other extraneous attachments, e.g. street lighting and CCTV cameras, should not be fixed directly to the main structure but taken through it in such a manner as to avoid contact with the cladding.

8.8 Movement and storage of materials

*COMMENTARY ON **8.8***
Attention is drawn to the Lifting Operations and Lifting Equipment Regulations (LOLER) 1998 [5], Construction (Design and Management) Regulations 2007 [6], and Manual Handling Operations Regulations 1992 [7] when considering lifting points and methods.

8.8.1 General

To avoid damage to the units, the stresses induced at all stages of handling whether in the factory, during transport or on-site, should be related to the strength of the particular units at any time of any of these operations. Handling should be planned and reduced to a minimum. Thin worked stones, such as marbles and granites, should be handled individually unless boxed or crated, but always on edge. Soft, non-staining packing or spacers between stones (particularly polished stones) should be used.

Units should not be "walked" on their edges.

8.8.2 Lifting methods and identification

Lifting methods and handling positions, especially for large stones, should be clearly defined and, where necessary, special facilities (e.g. bolt holes or Lewis holes) should be provided. In addition, identity, location and orientation marks should be clearly marked on the units.

Lifting should be designed to require the minimum effort on site.

8.8.3 Transport stage

It is often advantageous for units to be transported in the plane in which they are fixed in the building. The design of racks and other equipment for large units for transport should be suitable, and allowances made for the flexing of the vehicle platform. Details of any temporary supports and their positioning should be shown on the drawings.

8.8.4 Erection stage

Lifting areas should be selected so that the units clear all permanent and temporary structures during the lift.

8.8.5 Storage of materials

Cement and lime should be stored off the ground on a timber floor in a dry structure.

Sand should be stored away from other materials to avoid it becoming contaminated. The storage of sealants should be in accordance with the manufacturer's instructions. In particular, sealants should not be stored in low temperature conditions.

8.8.6 Stacking of units during transport and storage

Every precaution should be taken against overstressing or damage by the provision of suitable packing at designed points of support. There are considerable dangers of breaking and damage by supporting other than at two positions, and also by the careless placing of packings (e.g. not vertically one above the other). Stacking should be arranged to prevent the accumulation of trapped water or rubbish between the units. In particular, prolonged damp conditions should be avoided as this can cause staining from wet packings.

Where site storage is necessary, it should be arranged in erection sequence, with markings visible and with access for the lifting gear.

Clear storage on-site is essential for all stonework delivered. The storage areas should be protected from the weather and clear of all other operations. For work involving highly finished or polished units, it is essential to have safe, dry and internal storage areas set apart from main traffic runs.

8.9 Bedding, jointing and sealing

8.9.1 General

All jointing surfaces should be cleaned free of dirt, dust, grease or other deleterious material.

8.9.2 Mortar-filled joints

For mortar-filled joints the bedding surfaces of small units should be well wetted and the units stood on a full bed of mortar and tapped home.

For very large or heavy units, a mortar bed should be screeded level and full but kept back 20 mm from the face, before the stone is lowered into place. All joints should be as completely filled as possible and if it is necessary to pour grout into vertical joints in order to achieve this, it is essential that the front and rear edges of units are adequately buttered beforehand, to prevent any grout escaping into the cavity or externally. With mortar-filled joints, preformed and compressible backer rod may be used at the rear edge to prevent any loss of mortar into the cavity.

Mortar on the surface of the stones should be avoided as it can be difficult to remove without damaging the stone or leaving some residue behind.

8.9.3 Mortar mixes

Materials for mortars should conform to BS 8298-1:2010, **5.3**. The type of mortar used for the jointing and pointing of units depends heavily upon the type, size and surface finish of the cladding and the extent of its exposure to severe weather conditions. Pointing mortar should be frost resistant when set and of similar strength to the jointing mortar; neither should be stronger than the stone.

For limestone and sandstone work, a mortar of 1:1:5 or 1:1:6 cement:lime:sand or 1:2:8 or 1:2:9 cement:lime:stone dust should be used.

NOTE "Stone dust" is matching crushed stone, e.g. crushed Portland for Portland stone, crushed Bath for Bath stone. Sand is the usual fine aggregate for sandstones.

For the narrow joints of granite, slate or similar units a cement:sand mortar should be used; usually 1 part cement to 3 parts sand. Joints wider than 4 mm should be filled with a much weaker mortar to reduce shrinkage cracks. For specific conditions, reference should be made to BS EN 1996-2.

The aggregate and/or stone dust used should be graded from coarse to fine where the coarse aggregate should be one-third of the width of the joint. Gap-graded and single-sized aggregate should not be used.

8.9.4 Sealant-filled joints

Where sealant-filled joints are used, the manufacturer's instructions should be followed.

NOTE Particular attention is drawn to the problems of applying sealants in unsuitable weather conditions.

8.10 Flashings and weatherings

Metal flashings and weatherings, which should be in accordance with **5.4**, should be securely anchored to avoid lifting due to wind action. Where they are tucked into a groove, the depth of tuck should be at least 25 mm and the joint adequately pointed. Aluminium flashings should be painted with bitumen of the solution (not emulsion) type, where they are likely to be in contact with concrete or mortar.

8.11 Protection

8.11.1 Protection against damage

Care should be taken to avoid damage from any cause at all stages. Packing pieces used for protection should not disfigure or otherwise permanently mark the units.

Surface protection should be afforded by careful handling and the avoidance of the use of hooks, crowbars, or other implements that are likely to damage the stone. Oils, grease, paint, cement slurry and liquid agents liable to cause staining should not be used in close proximity to the area in which the units are stacked.

8.11.2 Protection during construction

Decorative surfaces should be protected during construction by a temporary cover.

8.11.3 Protection of finished work

At all stages it is essential that all units are properly protected.

Particular attention should be given to permanently exposed surfaces, especially arrises and decorative features. The protection may be by timber strips, hessian or polyethylene, but should not be such as is likely to damage, mark, or otherwise disfigure the units.

Polyethylene heavy duty sheeting can be used as protection against rain, snow and frost. It might be necessary in certain cases to avoid contact with the units.

Timber battens protecting sills or other arrises should remain in position as long as possible. Where slurry is applied, this also should remain in position as long as possible.

Suitable packing should be used so that scaffolding does not damage erected units. Steel scaffolding can be a source of rust stains, particularly if putlog holes are not blocked off to prevent rust-stained rainwater from being blown on to the surface of units.

Work on the upper stages of the structure should not be allowed to contaminate lower levels.

Unless special precautions are taken for winter working, the use of mortar should be avoided at temperatures of 2 °C or below. It is essential that joints are protected against frost.

8.12 Site repairs

Superficial damage to stone may be repaired on-site with the consent of the architect, structural engineer or other authorizing agents but even cosmetic repairs should not be made to more than a small proportion of units as such repairs are likely to have a limited life. When deciding whether or not the damage is superficial, consideration should be given to its extent and location in relation to supports, fixings and corners.

Filling of stone should not be regarded as an on-site repair procedure and should only be carried out at the manufacturer's works.

8.13 Cleaning on completion of work

On completion of building operations, the face of the unit should be cleaned of all dust, rust and other stains, adhering mortar and other droppings. The scaffolding should be struck as cleaning down proceeds to avoid back-splashing from scaffold boards and rust staining from scaffold tubes on to completed work.

All cleaning should be in accordance with BS 8221-1 and BS 8221-2.

9 Maintenance

9.1 General

Cleaning and surface repair should be in accordance with BS 8221-1 and BS 8221-2.

Where nameplates or other fitments that require regular cleaning are fixed to cladding, measures should be taken to avoid staining the surrounding stone during the cleaning operation. A masking plate that fits tightly around the nameplate or fitment should be provided.

9.2 Compression and movement joints

During routine maintenance, compression and movement joints should be examined to check their continuing effectiveness. When replacing sealants, weak or friable surfaces should be strengthened on their surface with a primer/binder, where necessary, together with the use of a low modulus sealant for any replacement seals.

9.3 Pointing

Any pointing that has suffered from frost or by movement of the frame should be raked out and the joints repointed at the time cleaning is carried out.

9.4 Lime bloom

NOTE Lime bloom, a stain somewhat similar in appearance to that of efflorescence, is unlikely to appear on natural stone. It is caused when carbon dioxide (dissolved in water) reacts with free lime, produced during the setting of Portland cement, to form an insoluble deposit of calcium carbonate.

Lime bloom should be allowed to weather off naturally.

9.5 Granite

NOTE Most granite with a polished face retains its polish and colour for a great many years and the only maintenance required is regular washing with clean water to remove surface dirt.

Granite facings with a textured finish normally require only occasional washing with clean water to remove surface dirt, but it might be necessary in some atmospheres, particularly if maintenance has not been carried out for some considerable time, to assist the removal of the dirt with a bristle or soft wire non-ferrous brush, or to use proprietary cleaning liquids; however, such cleaning should be undertaken strictly in accordance with the manufacturer's instructions in each case and a small sample area should be treated first.

9.6 Marble

9.6.1 External marble with honed finish

Usually, only marble of the lighter colours is appropriate in external locations and very little maintenance is necessary. It should be occasionally washed down with clean water, with a mild detergent added, if necessary.

9.6.2 External marble with polished finish

To retain a highly polished finish in exposed conditions, the marble should be thoroughly cleaned with water, and detergent if necessary, at least twice a year and a silicone clear wax polish applied with a buffer. If the marble is protected under a canopy, depending on conditions, the frequency can be less, e.g. 9 months to 12 months.

Black and dark-coloured marbles are not recommended externally as they lose their polish more rapidly but, if used, maintenance should be performed more frequently than for the lighter-coloured marbles.

9.6.3 Internal marble

If required, marble used internally should be occasionally washed down with clean water.

NOTE A mild detergent may be added, if necessary.

9.7 Slate and quartzite

Slate and quartzite should be inspected periodically for any delamination and repointing where necessary, but no other maintenance is normally required, other than washing.

9.8 Limestone and sandstone

In town atmospheres, stone facing acquires a coating of dust and dirt. To maintain the colour and texture of the stone and to aid the reflection and diffusion of light from the building's surfaces, it is recommended that the face is cleaned every 5 years to 10 years according to the amount of discolouration the facing suffers.

Washing with clean water and scrubbing with bristle brushes should be undertaken to maintain the appearance of stone work and remove atmospheric deposits conducive to decay.

Annex A (informative) Sampling of natural stone

*NOTE There is a requirement within the European Standards, e.g. BS EN 1469, for stone suppliers to provide a sampling plan and sampling reports to demonstrate the sampling regime used to produce the stone test data required by the standards. General guidance on the sampling plan, sampling reports and sampling regime can be found within the European Standards. Specific guidance on the implementation of the sampling plan, sampling reports and sampling regime is given in **A.1**, **A.2** and **A.3**.*

A.1 Sampling plan

The sampling plan is prepared by the sampler prior to sampling for all types of testing, whether initial, pre-production or production testing. The sample plan needs to include details of the following:

a) the type of the natural stone in accordance with BS EN 12440 and BS EN 12670;

b) the aim of the sampling including a list of the properties to be tested;

c) the identification of sampling points, to include quarry plan identifying area(s) from which samples will originate;

d) the approximate size of samples;

e) the number of samples;

f) the sampling apparatus to be used;

g) the methods of sampling;

h) the marking, packaging and dispatch of the samples.

Table A.1 shows an example of a comprehensive sampling plan.

A.2 Sampling report

The sampling report is prepared by the sampler for each sample or batch of samples from a single source. The sample report needs to include details of the following:

a) the sampling report identification (serial number);

b) the laboratory sample identification mark(s) (to be completed by the testing laboratory);

c) the date and place of sampling;

d) the sampling points(s) or identification of the batch sampled;

e) reference to the sampling plan;

f) the name of the sampler.

Table A.2 shows an example of a comprehensive sampling report.

A.3 Sampling regime

The specific provisions of the European Standards need to be followed when sampling for testing. The following points are of particular importance:

a) the aim of sampling is to obtain a sample that is representative of the average properties of the batch and of its variability;

b) proper and careful sampling and sample transport is a prerequisite for an analysis that will give reliable results.

Table A.3 shows examples of how representative samples can be achieved with the provision of control samples for future re-testing/inspection.

Table A.1 **Example sampling plan**

Sampling plan		***Sampler to complete this column***
Sampling plan no.:		
Project details		
Project name:		
Project ref. no.:		
Company for whom sampling plan undertaken:		
Company sampling plan prepared by:		
Stone details		
Name of quarry or factory:		
Name of stone:		
Location of sampling points:		***To be identified on an attached quarry plan***
Tests for which samples to be used		
Test	***Insert test name***	
Quantity	Sample size	Bed orientation
Test	***Insert test name***	
Quantity	Sample size	Bed orientation
Test	***Insert test name***	
Quantity	Sample size	Bed orientation
Test	***Insert test name***	
Quantity	Sample size	Bed orientation
Test	***Insert test name***	
Quantity	Sample size	Bed orientation
Test	***Insert test name***	
Quantity	Sample size	Bed orientation
Samples		
Method of obtaining samples:		
Apparatus to be used for sampling:		
Comments		
This sampling plan has been prepared by <insert company name>, please contact <insert contact name>, Tel. No. <insert contact number> if further information is required.		

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Table A.2 **Example sampling report**

Sampling report	***Sampler to complete this column***
Sampling report no.:	
Sampling ref. no.(s):	
Laboratory ref. no.:	***To be completed by the testing laboratory***
Project details	
Project name:	
Project ref. no.:	
Company for whom testing undertaken:	
Name of company producing samples:	
Stone details	
Name of quarry or factory:	
Name of stone:	
Location of sampling points:	***Insert Sampling Plan ref. no.***
Origin of sample(s):	***Insert block identification no.***
Stone end use:	
Samples	
Tests for which samples to be used:	
Size:	
Quantity in batch:	
Orientation:	
Method of obtaining samples:	
Sample verification	
Person responsible for cutting samples:	Print name: Signature:
Date samples cut:	
Date samples despatched:	
Comments	
This sampling report has been prepared by <insert company name>, please contact <insert contact name>, Tel. No. <insert contact number> if further information is required.	

Table A.3 **Sampling for representative samples**

Test cubes 1	Control cubes 1
Control cubes 2	Test cubes 2
Test cubes 3	Control cubes 3

NOTE General layout to achieve representative test samples from a slab. The layout demonstrates the principle of sampling across the range of the slab where 6 sample cubes are required for a test. Samples are not to be cut from the outside 100 mm of the slab.

Annex B (informative) Example of calculation of thermal movement

For this example, the building construction type is an enclosed concrete frame with light granite cladding. Ambient temperature at the time of fixing is 15 °C. Before being clad, the frame can be regarded as being fully exposed, and has a temperature of 40 °C. If the cladding is stored out of direct sunlight its temperature might be 20 °C. At the time of fixing, the difference in length between frame and cladding is taken as zero.

On a hot summer's day with the building complete and occupied, the relative movement, *M*, (in mm) of frame to cladding is given by the equation:

$$M = 1000\left\{\left(t_{fs} - t_{fe}\right)\alpha_f - \left(t_{cs} - t_{ce}\right)\alpha_c\right\}$$

where:

t_{fs} is the temperature of frame in summer (in °C);

t_{fe} is the temperature of frame on erection of cladding (in °C);

α_f is the coefficient of thermal expansion of frame;

t_{cs} is the temperature of cladding in summer (in °C);

t_{ce} is the temperature of cladding on erection (in °C);

α_c is the coefficient of thermal expansion of cladding.

Using the following values t_{fs} = 30 °C, t_{fe} = 40 °C, $\alpha_f = 13 \times 10^{-6}$ per °C, t_{cs} = 50 °C and t_{ce} = 20 °C then:

If $\alpha_c = 5 \times 10^{-6}$ per °C,

$$M = 1000\left\{(30-40)13\times10^{-6} - (50-20)5\times10^{-6}\right\}$$

M = –0.28 mm/m;

If $\alpha_c = 10 \times 10^{-6}$ per °C,

M = –0.43 mm/m.

In a sharp winter frost, the movement of the frame relative to the cladding is given by the equation:

$$M = 1000\left\{(t_{fw} - t_{fe})\alpha_f - (t_{cw} - t_{ce})\alpha_c\right\}$$

where:

t_{fw} is the temperature of frame in winter (in °C);

t_{cw} is the temperature of cladding in winter (in °C).

Using the following values t_{fw} = 10 °C and t_{cw} = –20 °C then:

If $\alpha_c = 5 \times 10^{-6}$ per °C, M = –0.19 mm/m.

If $\alpha_c = 10 \times 10^{-6}$ per °C, M = 0.01 mm/m.

NOTE The negative signs mean that the frame gets shorter relative to the cladding, i.e. joints between adjacent units tend to close up.

Thus, taking the worst case, if the distance between expansion joints is 3.5 m, a movement of 0.43 × 3.5 mm = 1.5 mm is allowed for. The 1.5 mm calculated in this example is the extension that the sealant would be expected to accommodate.

Thus, if the sealant to be used can accommodate a strain of 10%, a joint of 15 mm would be needed to accommodate a movement of 1.5 mm.

Bibliography

Standards publications

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

BS 6093:2006, *Design of joints and jointing in building construction – Guide*

BS 6213:2000, *Selection of construction sealants – Guide*

BS EN ISO 9000 (series), *Quality management systems* [2)]

BS 970-1:1991, *Specification for wrought steels for mechanical and allied engineering purposes – Part 1: General inspection and testing procedures and specific requirements for carbon, carbon manganese, alloy and stainless steels* [3)]

BS 1449-2:1983+A4:1997, *Steel plate, sheet and strip – Part 2: Specification for stainless and heat-resisting steel plate, sheet and strip* [3)]

BS 6093, *Design of joints and jointing in building construction – Guide*

BS 6213, *Selection of construction sealants – Guide*

Other publications

[1] CIRIA. *Manual of good practice in sealant application*. Special Publication SP 80. London: CIRIA, 1991.

[2] GREAT BRITAIN. Building Regulations 2000 (as amended). London: The Stationery Office.

[3] SCOTLAND. The Building (Scotland) Regulations 2004. Edinburgh: The Stationery Office.

[4] GREAT BRITAIN. Building Regulations (Northern Ireland) 2000 (as amended). London: The Stationery Office.

[5] GREAT BRITAIN. The Lifting Operations and Lifting Equipment Regulations (LOLER) 1998. London. The Stationery Office.

[6] GREAT BRITAIN. The Construction (Design and Management) Regulations (CDM Regulations) 2007. London: The Stationery Office.

[7] GREAT BRITAIN. The Manual Handling Operations Regulations 1992. London: The Stationery Office.

2) In the Foreword only.

3) This standard is withdrawn and has been included purely for historical clarification.

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