BS 8298-3:2010

BSI Standards Publication

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

Part 3: Stone-faced pre-cast concrete cladding systems

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Contents

Summary of pages
This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 10, an inside back cover and a back cover.

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Foreword

Publishing information

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with BS 8298--1, BS 8298-2, BS 8298-4 and BS 8298-5 [1)], this part of BS 8298 supersedes BS 8298:1994, which is withdrawn.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

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

- BS 8298 has been completely restructured by splitting it into five parts;
- the BS 8298 parts have been updated to reflect general changes in the fixings systems available to support natural stone cladding panels.

BS 8298-1 contains the terms and definitions for all the parts of BS 8298.

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.

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.

1) In preparation.

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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 natural stone directly attached to pre-cast concrete units (i.e. stone faced concrete cladding units).

Loadbearing stones or stones held only by adhesion are not included, nor is any type of stonework supported or held in position around the perimeter of stones or series of stones by metal framing.

Guidance on the design of the precast concrete unit is given in BS 8297.

This part of BS 8298 is to be read in conjunction with BS 8298-1. Different cladding and lining methods are covered in the other parts of BS 8298 (see Foreword).

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 5606, *Code of practice for accuracy in building*

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

BS 8297, *Code of practice for Design and installation of non-loadbearing precast concrete cladding*

BS 8298-1:2010, *Code of practice for the design and installation of natural stone cladding and lining – Part 1: General*

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

3 Terms and definitions

For the purposes of this part of BS 8298, the terms and definitions given in BS 8298-1 apply.

4 Exchange of information and time schedules

4.1 General

The exchange of information and time schedules should be in accordance with BS 8298-1 and the additional recommendations given in **4.2** and **4.3**.

4.2 Design and performance specification

The following information should be sought from the stone supplier to allow an assessment of the material to be made:

a) flexural strength;

b) apparent density and open porosity;

c) water absorption at atmospheric pressure; and

d) fixing tests on composite samples (see Annex A for a typical test method).

4.3 Facilities and materials required on site

As stone facing is normally attached to the backing panels at the pre-cast works, there is relatively little site activity involving stone elements. However, in some cases limited numbers of stone pieces might need to be attached to the backing panels on site and due provision should be made for access, working space and the lifting/delivery of stone pieces to the point of attachment.

5 Thickness of stone

The thickness of stone selected should be:

a) determined by structural calculation with the most important consideration being the resistance of the fixed stone facing to negative wind pressures;

b) in accordance with Annex B, where no testing information is available.

The resistance to negative wind pressures should be demonstrated by calculation, taking into account the expected imposed loads and the number of fixings (see Clause **6**) and the load required to pull the stone from the backing.

A factor of safety of 8 should be included in these calculations.

6 Methods of attachment and support

6.1 Design

The fixing to the pre-cast concrete backing panel should accommodate the weight of the stone slab supported and any imposed loads, for example:

a) wind loads;

NOTE 1 Guidance on typical wind loads is given in BS EN 1991-1-4.

b) access platforms and other loads that might be applied during the life of the building;

c) loads caused by snow and ice accumulating on ledges and projections;

d) impact loads. At lower levels, these might need to be considered in relation to thin nibs and projections (see BS 8298-1 for loading criteria). For flat stones fixed to a concrete backing it would be normal to assume that the concrete backing carries the loading.

Account should also be taken of irregular shaped stones and projections (e.g. quoin stones and cornice stones) which might result in loads to the fixings higher than those associated with simple flat slabs.

It is essential that the method of attachment enables the stone to be permanently attached to and supported by the pre-cast concrete backing panel. The method of attaching the panel to the structure should be in accordance with BS 8297.

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

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NOTE 2 The maximum dry weight of cladding stones ranges from 2 500 kg/m^3 for limestone to 2 750 kg/m^3 for granite. Therefore, as a general guide, a figure of 3 000 kg/m^3 can be used to calculate the maximum likely load to be carried, which also allows for cladding stones having a +3 mm tolerance.

The fixing method should be proved by structural calculations and backed up by test results, where appropriate.

NOTE 3 An example method is given in Annex A.

6.2 Stainless steel dowel pins

6.2.1 General

Where stainless steel dowel pins are used for attaching stone (see Figure 1):

a) the dowels should be not less than 4.7 mm in diameter inclined at approximately 45° to 60° to the back of the stone;

b) approximately 50% of the dowels should be reversed in direction;

c) each dowel should be fitted with a flexible grommet with a wall thickness not less than 3 mm;

d) the depth of penetration of the dowel into the stone should be two-thirds of the thickness of the stone and the depth of the hole should be no greater than the dowel pin diameter +2 mm;

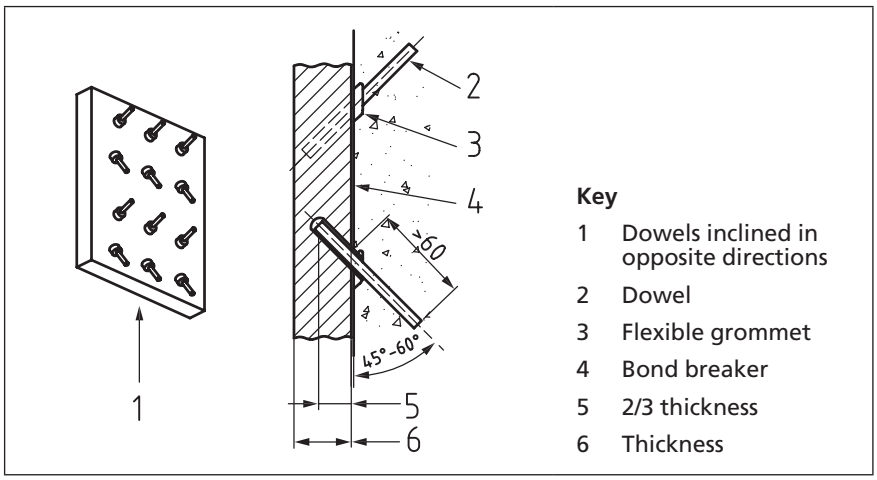
e) the embedded length of the dowel into the concrete should be not less than 60 mm;

f) small, narrow or irregular shaped stones should be supported by a sufficient number of fixings;

g) the bottom edges of stones which do not have a physical support or another stone immediately below them should have fixings not more than 100 mm above the edge and also within the reinforcement cage;

h) a bond breaker should be provided between the rear of the stone and the backing concrete, to allow for differential movement.

Figure 1 **Typical details of fixing plate for stone-faced concrete units**



6.2.2 Number of pins

The number of pins required should be demonstrated by a test applying a factor of safety of 8. In the absence of test data and where stones are provided in accordance with Annex A not less than 11 stainless steel pins per square metre should be provided.

6.3 Proprietary fixings

Where alternative fixings which are specifically intended for attaching the stone element to a backing medium are to be used then the design of proprietary fixings should be based on the manufacturer's recommendations for safe loads providing the supplier is able to demonstrate recent test results for the type of stone proposed.

7 Jointing and pointing

7.1 General

NOTE 1 Typical joints are shown in Figure 2.

A joint might need to be loadbearing, or to accommodate movements of the cladding and any movement of the superstructure which can be transmitted to the cladding; in all cases, joints should be weathertight. Joints should always take account of the respective manufacturing, setting out and assembly deviations of the materials used in accordance with the requirements of BS 5606 and BS 6093.

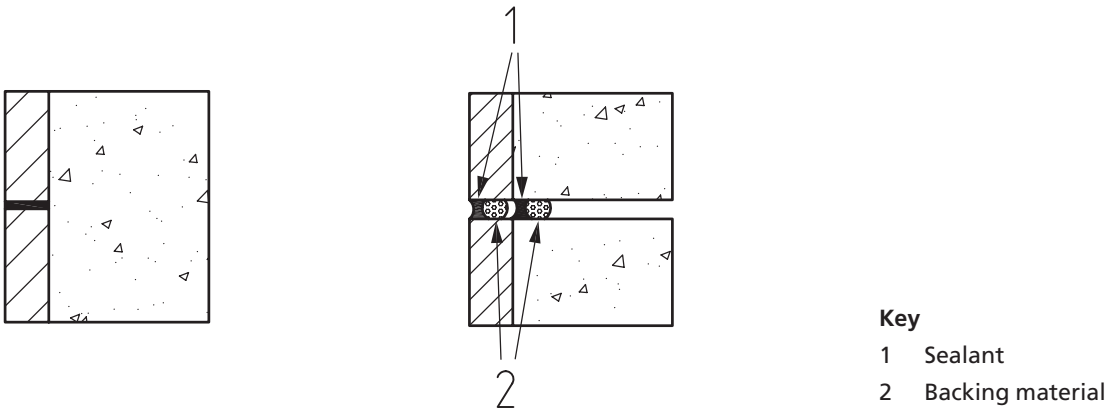
When considering the type of joint to be used, the following points should be taken into account.

a) The joint should be simple so that reasonable manufacturing tolerances can be allowed and the erection procedure is straightforward.

b) Allowance should be made for movements of the building and dimensional changes in the joints between units.

NOTE 2 The type of jointing or pointing depends upon the type, size, thickness and surface finish of the cladding units and also its location on the building, environmental condition, aesthetic requirements and designed life.

Figure 2 **Types of joints**



7.2 Unfilled joints

Butt joints should not be used.

NOTE With butt joints, any movement of the units cannot be absorbed and would, therefore, be transmitted between the units, and these might become damaged as a result. This movement could occur during fabrication, handling of the backing panel, or in service. In addition, any slight out-of-squareness of the units or irregular abutting would cause point loading which, in turn, would lead to damage at these points.

Open joints are sometimes used as a design feature but, if external, should only be used where the effect of water penetration to the cavity has been fully assessed and allowed for.

7.3 Filled joints other than compression and movement joints

7.3.1 Cladding

*COMMENTARY ON **7.3.1***
Joints in external cladding, particularly sandstone and limestone, are usually filled with cement and sand or cement, lime and sand mortars. Lime mortars using naturally hydraulic lime and sand or stone dust can also be used. Increasingly for granite, slate and marble, an approved sealant is used.

Where mortar is used, the cladding should be bedded and pointed with the same mortar as one operation, even if it is a special colour, as all mortar is then homogeneous.

NOTE If it is necessary to introduce colours as a separate operation, the joints can be raked out to a minimum depth of 13 mm as the work proceeds.

7.3.2 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, to the requirements of BS EN 1996-2 should be followed.

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.

7.3.3 Width of joints

The maximum width of mortar-filled joints should be 13 mm, but sealant-filled joints can be up to 30 mm wide subject to the manufacturer's advice. The minimum width of joints should generally be in accordance with Table 1, which allows for cutting tolerances.

NOTE Where specially required, the minimum width can be reduced but this can demand extra precision in production of the stones.

Where narrower joint widths are required, face dimensions tighter than those shown in BS 8298-1:2010, **7.2.2**, might be necessary; where tighter cutting tolerances are required, these should be agreed between the specifier and supplier prior to tender.

If the joint width is less than that given in Table 1, the implications for jointing material should be determined at the tender stage.

Table 1 **Minimum width of joints**

Stone	Minimum width of joint	
	Mortar	Sealant
	mm	mm
Granite, marble and slate	3	5
Slate with riven finish	7	5
Limestone and sandstone	5	5

7.4 Compression and movement joints

7.4.1 General

Compression and movement joints should be in accordance with **7.4.2** and **7.4.3** but account should be taken of the time between construction of the frame and erection of the cladding. The shorter the period between these operations the bigger the joints should be. No grout or mortar or other material should be allowed to accumulate in the joint. Before application of a flexible sealant, all joints should be cleaned and inspected.

7.4.2 Compression joints

Compression joints should be avoided between stones as the supporting fixings might be overloaded if loads are transmitted from one stone to another.

7.4.3 Movement joints

Movement joint should be situated between backing panels and not between individual stone pieces. Joints between stones at the perimeter of panels should be the same width as the joint between the panels.

NOTE The width is determined by the need for movement and limited by the need to introduce the sealant gun nozzle beyond the depth of the stone.

8 Accommodation of dimensional changes

NOTE 1 There is a degree of thermal movement between the stone facing exposed to external temperatures and sun, and the backing panel; although small, this movement can set up thermal stresses at the interface of the stone and concrete.

To allow free movement, it should be specified that the interface between the stone facing and backing panel is to be treated with a bond breaker during manufacture. The stainless steel dowel pins should include a grommet that allows lateral movement at the interface.

NOTE 2 See Figure 1.

9 Permissible deviations

Allowance should be made in the design for deviations in the erection of the structure and in the cladding and joints.

NOTE Deviations of cladding units are given in BS 8298-1, but (when erected) joint widths normally vary to take up these deviations.

If evenness of joint width is required, the use of purpose-made end units should be considered, since slight variations in dimensions of an occasional unit is likely to be less noticeable than wide variations in joint width between units. to the guidance in BS 5606 and BS 6093 should be followed.

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Annex A (normative) Alternative guidance for the assessment of panel thickness

Unless proved by structural calculation or performance testing (flexural strength/modulus of rupture), the thickness of stone should be in accordance with Table A.1, which is based on satisfactory past experience.

*NOTE The nominal thickness of stone is subject to the permissible deviations given in BS 8298-1:2010, **7.2.2**.*

Table A.1 **Panel thickness for stone-faced pre-cast concrete units**

Stone	Thickness
	mm
Granite	30
Limestone (e.g. Portland, Bath, Clipsham)	50
Homogenous marbles	30
Brecciated marbles	Not recommended
Quartzites	30
Slates (those unlikely to delaminate)	30
Sandstone (e.g. York, Northumberland, Scottish)	50
Travertines	30

Annex B (informative) Method of test for pre-cast fixing tests on natural stone-faced concrete samples

B.1 Sample

B.1.1 *Three stone pieces, with dimensions of 400 mm × 400 mm × 50 mm, on a 150 mm concrete backing*, each with four inclined, offset, opposing, stainless steel dowel pins installed.

B.2 Apparatus

B.2.1 *Base steel frame of rigid construction and fabricated such that the sample can be firmly attached at its base and such that the bridging unit is solidly seated.*

B.2.2 *Loading system, e.g. hydraulic ram with calibrated load cell.*

B.2.3 *Bridging unit of rigid construction and fabricated such that the 'loading system' can be installed between the bridge and the steel plate coupling.*

B.3 Preparation

Embed a threaded coupling in the back of the concrete on each sample.

Prior to test, resin-bond a steel plate, with dimensions of 300 mm × 300 mm × 20 mm, with a centrally welded loading coupling to the centre of the finished surface of the stone on each sample and allow to cure.

B.4 Procedure

Bolt the sample rigidly on to the base steel frame.

Apply a load to the stone piece on the sample through the steel plate coupling (i.e. duplicating negative wind loading on the stone) by means of a loading system, reacting upon a bridging unit.

Place the bridging unit spanning the sample so that its feet rest on the base steel frame.

Apply the load vertically and evenly (to prevent shock loading) until failure occurs.

Record the load at failure and/or peak load if slippage occurs, e.g. "5 kN, failure" or "4 kN, slippage".

NOTE A typical report form is shown in Figure B.1.

Figure B.1 **Typical report form**

Rock name			Tested by/Date	
Rock type			Checked By/Date	
Specimen reference	Simulated wind loading [A)]	Failure/peak load (kN)	Observations	
	Negative			
	Negative			
	Negative			
Mean max. load				

[A)] Negative : pulling from front of panel

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 8298-2, *Code of practice for the design and installation of natural stone cladding and lining – Part 2: Traditional handset external cladding*

BS 8298-4, *Code of practice for the design and installation of natural stone cladding and lining – Part 4: Rainscreen and stone on metal frame cladding systems*[2)]

BS 8298-5, *Code of practice for the design and installation of natural stone cladding and lining – Part 5: Internal linings*[2)]

BS EN 1991-1-4, *Eurocode 1 – Actions on structures – Part 1: General actions – Wind actions*

BS EN ISO 9000, *Quality management systems – Fundamentals and vocabulary*

[2)] Referred to in Foreword only.

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