BS 8298-4:2010

BSI Standards Publication

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

Part 4: Rainscreen and stone on metal frame 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 22, 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with BS 8298-1, BS 8298-2, BS 8298-3 and BS 8298-5 [1)], this part of BS 8298 supersedes BS 8298:1994, which is withdrawn.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.

Presentational conventions

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

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 and fixing of slabs of natural stone onto an intermediate metal framing system (which in turn is fixed to the building structure) as part of a ventilated rainscreen cladding system.

Recommendations are also given on the fixing of stone to metal framing systems as part of a non-ventilated rainscreen cladding system.

It covers:

a) the provisions necessary for the cladding to perform its function satisfactorily;

b) the materials and methods most frequently used for stonework;

c) the use of thermal insulation behind external cladding.

It does not cover aggregate/agglomerated stone, roofing slate or terracotta panels used as external cladding.

This part of BS 8298 considers the use of stone cladding in all orientations, including vertical and sloping elements of the façade as well as soffit and coping panels. All methods of fixing are considered.

Recommendations for soft body impact testing are included, but not hard body.

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 648, *Schedule of weights of building materials*

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

BS 7671:2008, *Requirements for electrical installations – IEE Wiring Regulations – Seventeenth edition*

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

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

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

BS EN 1991-1-3, *Eurocode 1 – Actions on structures – Part 1: General actions – Snow loads*

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

BS EN 12153, *Curtain walling – Air permeability – Test method*

BS EN 12155, *Curtain walling – Watertightness – Laboratory test under static pressure*

BS EN 12600, *Glass in building – Pendulum test – Impact test method and classification for flat glass*

BS EN 13161, *Natural stone test methods – Determination of flexural strength under constant moment* [2)]

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

BS EN ISO 6946, *Building components and building elements – Thermal resistance and thermal transmittance – Calculation method*

BS EN ISO 10211, *Thermal bridges in building construction – Heat flows and surface temperatures – Detailed calculations*

BS EN ISO 13788, *Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods*

BS EN ISO 13789, *Thermal performance of buildings – Transmission and ventilation heat transfer coefficients – Calculation method*

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

NOTE Guidance on the need for timely exchange of information and planning is given in BS 8298-1.

As a ventilated rainscreen cladding system is a high performance façade system, the necessary performance for the system should always be carefully specified by the project engineer.

5 Materials and components

5.1 General

NOTE 1 Guidance on the selection of materials is also given in BS 8298-1.

All materials and components should be used in accordance with the manufacturer's instructions.

NOTE 2 Failure to observe the manufacturer's instructions can invalidate any warranty that is offered on the complete wall system.

A ventilated rainscreen should have the following key elements:

a) An outer layer (the rainscreen), intended to shelter the building from the majority of direct rainfall. Some joints between panels or at the edges of the rainscreen should be left open.

b) A cavity, which can include insulation, intended to collect any water which passes through the joints in the rainscreen layer, and to permit such water to flow down to a point where it is collected and drained from the cavity. The insulation layer should not completely fill the cavity.

c) A backing wall, intended to provide a barrier to air infiltration and water ingress into the building.

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2) This standard also gives an informative reference to BS EN 13161:2008.

NOTE 3 All of the joints in the rainscreen system do not need to be open. Joints in copings and sill panels will typically be sealed, as might joints in soffit panels. Vertical and horizontal joints on the face of the wall might be all open, or either the vertical or horizontal joints might be sealed. The most typical case, however, is for all of the joints on the face of the wall to be left open.

If open joints are to be used at low level, consideration should be given to the possibility of items being inserted into the joints by members of the public; rainscreen cladding might therefore not be appropriate at low level on publicly accessible buildings.

NOTE 4 A ventilated rainscreen cladding system is either pressure-equalized or drained-and-ventilated.

5.2 Pressure-equalized rainscreen cladding

For a rainscreen cladding system to be classed as pressure-equalized, the cavity behind the rainscreen panels should be subdivided into compartments so that:

a) the width and height of each compartment is limited in size, depending upon its location on the building;

b) the clear air gap behind the panels exceeds a minimum depth, which is dependent upon the design of the joints;

c) only those joints that exceed a defined minimum width are classed as "open";

d) the minimum free area of the "open" joints exceeds a certain proportion of the volume of the compartment; and

e) provision is made to intercept water that drains down the cavity at suitable intervals, and to drain such water to the outside of the rainscreen layer.

5.3 Drained-and-ventilated rainscreen cladding

If the rainscreen cavity is not compartmented in accordance with the recommendations for a pressure-equalized system, it should only be classed as drained-and-ventilated provided that:

a) the clear air gap behind the panels exceeds a minimum depth, which is dependent upon the design of the joints;

b) only those joints which exceed a defined minimum width are classed as open;

c) provision is made to intercept water which drains down the cavity at suitable intervals, and to drain such water to the outside of the rainscreen layer.

5.4 Rainscreen

5.4.1 General

NOTE The rainscreen panels shelter the remainder of the façade construction (the cavity and the backing wall) from direct wetting by rainfall. It is accepted that water might penetrate through the open joints, but steps can be taken to minimize this water ingress.

Water that passes through open joints should not penetrate to the backing wall, and should be collected at intervals and drained to the outside of the wall.

Any type of stone which can be used for cladding systems as described in BS 8298-1 can be used as part of a rainscreen cladding system, subject to the design of the rainscreen system meeting the recommendations of this part of the standard; the design of stone panels for cladding systems should be in accordance with BS EN 1469.

5.4.2 Stone fixings

The stone panels should be fixed using any of the methods described BS 8298-1; it is also possible, however, to fix the stone panels to a proprietary framing system, which in turn is fixed to the building structure.

NOTE The general principles of fixing to an intermediate framing system are the same as those for fixing the stone panels directly to the building's primary structure.

5.4.3 Framing systems

*COMMENTARY ON **5.4.3***
Intermediate framing systems provide considerable benefits with regard to the speed with which stone cladding can be set, and many systems provide for individual stones to be removed and replaced relatively easily.

The framing system typically comprises a grid of vertical and horizontal metal profiles, usually extruded from aluminium. Some systems use only horizontal frames, whilst others use vertical frames, or a combination of both. The frames can be secured to the building's primary structure in different ways, depending upon the nature of the structure.

If the façade of the building has a continuous backing wall which is sufficiently strong to support the proposed fixings, the framing members can be fixed at regular intervals. The spacing of the fixings is determined by reference to structural calculations and the properties of the particular fixing type. For a framing system that has both vertical and horizontal frames, it can be the case that only the vertical frames are connected directly to the building structure, with the horizontal frames fixed to the vertical, or vice versa.

5.4.3.1 General

If the primary structure of the building comprises an open concrete or steel frame, the rainscreen panel framing system can only be attached to the building at discrete points, typically at every floor slab. In this case, there should be at least two independent fixings at each fixing location, each designed to support the full loads acting on the rainscreen system at that point.

NOTE This system provides redundancy if one fixing fails.

If a framing system is to be applied to an existing structure, the façade designer or project structural engineer should demonstrate that the existing structure is sufficiently strong to support the weight of the rainscreen system and any such loads as might be applied to the rainscreen system.

As horizontal framing members directly behind the stone panels might restrict the flow of water down the back of the panels, a gap should be created between the face of the horizontal rails and the back of the stone panels.

5.4.3.2 Movement

If the framing system spans across several floors, connections should be such that the building's primary structure can move relative to the rainscreen system without applying loads to the rainscreen system.

The façade designer should establish the primary structural movements that need to be allowed for, and the circumstances in which those movements occur (some movements, such as initial building settlement, might have already occurred before the rainscreen system is fixed, particularly for overcladding projects on existing buildings). The façade designer should consider the effects of dead loads, live loads, creep, settlement and thermal and moisture movements. Where necessary, the façade designer should accommodate thermal and moisture movement of the stone panels and framing system, and should ensure that allowance is made to accommodate such movements, which can be in addition to the building's primary structural movement. Allowances should also be made for the potential effect of construction tolerances on movement joint widths.

Aluminium has a coefficient of thermal expansion that is considerably higher than that of stone or other materials, and framing that is trapped in the cavity outboard of an insulation layer can reach temperatures similar to those of the stone panels. Unless it can be shown otherwise, it should be assumed when calculating thermal movements that components in the cavity will experience temperatures between –20 °C and 65 °C.

The framing system should allow for thermal expansion and contraction of both the horizontal and vertical framing members.

The vertical framing members should be fixed to the building structure with a dead load connection at one position only. All other connections should allow for sliding of the framing members relative to the brackets.

Vertical framing members will typically span no more than one or two storeys to minimize the likely thermal expansion or contraction. Connections between consecutive lengths of frame should feature a spigot, fixed to one frame only, to permit the connection to slide whilst maintaining the end-to-end alignment of the frames. Panels should not be fixed across such movement joints unless the fixings to one side of the movement joint have an allowance for movement equal to that of the movement joint.

5.4.3.3 Fixings

*COMMENTARY ON **5.4.3.3***
For a typical framing system there might be several stages to the connection between the stone panels and the building's primary structure, e.g.:

a) a screwed or bolted fastener or anchor securing a bracket to the building's primary structure;

b) the bracket;

c) a riveted, screwed or bolted fastener or anchor securing a vertical framing member to the bracket;

d) a riveted, screwed or bolted fastener or anchor securing a horizontal framing member to the vertical framing member;

e) a riveted, screwed or bolted fastener or anchor, or a snap-fit connector securing a bracket, plate or clip to the horizontal framing member;

f) the bracket, plate or clip;

g) a pinned, adhesive or other fastener or anchor which secures the stone panel to the bracket, plate or clip.

The stone should be fixed to the framing system using fixings of the type described in BS 8298-1, or by the use of proprietary clips which form part of the framing system.

The façade designer should provide structural calculations or test data to demonstrate the integrity of each element in this series of connections. In the case of screwed or bolted fixings, each connection should have a satisfactory level of redundancy, e.g. if one fastener or anchor fails, there should be another which is able to support the full design load. Due allowance should be made for the combination of direct and shear forces that might be applied to these connections.

NOTE 1 The direct fixing into the stone panel can comprise a dowel or plate which fits into a hole or kerf in the stone, or it can be an expansion anchor or other fixing type.

If the dowel, plate or anchor is secured using a sealant, resin or grout, this material should be considered to be part of the fixing system. If test data is available to prove the performance of the fixing system, this data should be considered to be invalid if any element of the fixing system is modified or changed. Similarly, if a particular proprietary sealant, adhesive or grout has been approved for use with the rainscreen system, substitutes should not be used unless evidence is provided to demonstrate that a similar or improved level of performance can be expected, and that the durability of the system is not adversely affected.

Dissimilar metals at fixings should be isolated in accordance with BS 8298-1:2010, **5.7**, so as to avoid bimetallic corrosion. It should always be assumed that the fixing zone is liable to wetting. In marine environments and for locations within 10 km of the sea or tidal estuaries, metals should be specified which have suitable levels of resistance to salt water. In particular, it should be noted that when drying out after severe weather the concentration of dissolved salts in water increases significantly, and salts can accumulate on horizontal surfaces or surfaces that are not rainwashed.

NOTE 2 It might also be appropriate to isolate certain materials, such as aluminium, from direct contact with cementitious materials.

It should not be assumed that the fixings each take an equal part of the applied loads. Under a uniform pressure (wind) load, the fixings can only assume equal loads:

a) if all of the fixings lie on a circle; and

b) if the fixings are arranged symmetrically; and

c) if the centre of the circle is the centre of pressure of the panel (i.e. the centroid).

For any other arrangement, the fixings carry different proportions of the total load and so the load carried by each fixing should be determined by the façade designer.

For a rectangular panel, two fixings should be used near the bottom of the panel and two fixings near the top, equally spaced with regard to the panel corners; the fixings can be applied to the horizontal edges of the panel or to the vertical edges, depending upon the method of connection to the building structure.

The fixings should not be installed in such a way as to generate stresses in the panel. If a panel is fixed with four fixings, the first three fixings can usually be tightened without generating stresses in the panel; if the fourth fixing is then overtightened to pull the panel into position, this generates bending stresses in the panel which reduce its reserve of strength. The fixings should always incorporate sufficient out-of-plane adjustment to allow the panel to be installed without inducing bending stresses in the stone.

As it is not generally possible to support the weight of the panel on more than two fixings, the weight of the panel should be supported on two fixings, preferably those nearest the bottom of the panel (such that the weight of the panel generates mainly compressive stresses in the stone).

NOTE 3 If the weight of the panel is hung from top fixings, this generates tensile stresses in the remainder of the panel, reducing the reserve of strength of the panel.

The remaining fixings should act as restraint fixings, resisting wind and other applied loads, but permitting vertical movement of the panel to occur relative to the dead load fixings.

Testing should be carried out to demonstrate the strength of anchors, fasteners or dowels, which depends on their proximity to the edge and faces of the panel, and on their proximity to other fixings (e.g., if a bracket is secured to the reverse of a panel with two expansion anchors fitted a short distance apart the strength of connection would be less than twice the strength of a single anchor).

Anchors and fasteners should always be used in accordance with the manufacturer's instructions. If these components are to be used in a non-standard manner, the approval of the product manufacturer should be obtained.

Brackets which have horizontal upper surfaces might permit water to flow along the top of the bracket, bridging the air gap to the backing wall or insulation and, therefore, consideration should be given to providing a step-up or other feature to prevent such water movement from occurring.

NOTE 4 Components such as wall ties are often twisted to prevent the movement of water.

5.4.3.4 Deflections

If the framing system spans between floors of the building's primary structure, the façade designer should provide calculations or other evidence to demonstrate that the strength of the framing system is adequate, that the framing system will not deflect beyond acceptable limits, and that deflection of the framing system will not cause any component that is clipped to the framing system to spring free.

The deflection of the framing system should not give rise to damage to the stone panels, the framing system (including its fixings) and any linings and finishes that can be applied to the reverse of the framing system.

Movement occurs as the stone panels are fitted onto an intermediate framing system and the horizontal framing members should not be able to twist if this is liable to dislodge other panels, e.g. this can be avoided by using stiffer horizontal framing members or additional vertical framing members.

NOTE Typically, a horizontal framing member that supports several stone panels will deflect downwards at the middle unless vertical framing members are used at regular intervals. The mechanism by which the stone panels are fixed to the horizontal framing member might need to incorporate some form of levelling screw so that the horizontal joint widths are uniform. It might also be necessary to loose-fix all of the panels onto the horizontal framing member before levelling can begin, otherwise the addition of panels is likely to cause the first panels to be levelled to move out of alignment as the horizontal framing member dips further.

5.4.3.5 Dry linings

If the framing system is to incorporate dry linings or other finishes, these should be designed and tested as an integral part of the rainscreen system.

NOTE In a ventilated rainscreen system, considerable loads are transmitted to the backing wall.

5.4.3.6 Materials

Timber is not a suitable framing material for a stone rainscreen system, and timber should not be used in any part of such a system.

Materials should not be used behind the rainscreen layer unless their life expectancy, in the defined service conditions, is at least as great as that of the rainscreen layer itself, because inspection of materials in the cavity is difficult, even if permanent access is provided.

5.4.4 Joints

5.4.4.1 General

NOTE 1 The joints between stone panels are intended to permit air to circulate behind the panel, and to allow water to drain from the cavity. Whilst some water penetration can occur through these joints, this is minimal compared to the amount of water that is deflected by the rainscreen panels. The width of the joints is an important aspect of the performance of a rainscreen system. Water is able to bridge a gap less than 6 mm across, whilst snow and ice can bridge a gap less than 10 mm across.

The minimum width of a joint (i.e. the diameter of the largest cylindrical rod which can be rolled through the joint) should be as follows.

a) For a joint to be classed as "open" at all times, the minimum width should be 10 mm, allowing for the worst case accumulation of tolerances.

b) For a joint to be classed as free-draining, the minimum width should be 6 mm, allowing for the worst case accumulation of tolerances.

Narrow joints (i.e. those less than 6 mm wide) should be sealed or filled (see **5.4.4.2**) to resist water entry.

In a pressure-equalized rainscreen, some of the joints into every compartment should be open.

In a drained-and-ventilated rainscreen, the joints at the head and bottom of each cavity should be free-draining.

NOTE 2 The direct passage of water through a joint can be restricted by the use of narrow, sealed, baffled or labyrinth joints.

5.4.4.2 Sealed joints

A joint can be sealed by the use of a site-applied sealant, pre-formed gasket or foam tape. The material of the seal should be compatible with the stone and with any other material in the proximity of the sealed joint.

Sealed joints should conform to BS 6093.

If a foam tape is used to seal the joint, it should be noted that certain types of open cell foam provide a barrier to water penetration whilst still allowing air to flow through the joint.

The potential accumulation of dirt on seals should be taken into account as this can lead to pattern staining of the façade.

If a site-applied wet sealant is used to seal the joint, a suitable backer material should be located in the joint prior to applying the sealant.

All materials used for sealed joints should be compatible with the stone, and should not lead to problems with staining or discolouration of the stone.

5.4.4.3 Baffled joints

Baffled joints should conform to BS 6093.

An open baffled joint should have a minimum gap width (around one side or other of the baffle) of 10 mm at all times.

NOTE Framing members are commonly used to form baffles behind the joints.

5.4.4.4 Labyrinth joints

NOTE In a labyrinth joint, the edges of adjacent panels are shaped so as to overlap or interlock and prevent the direct passage of water.

Labyrinth joints should conform to BS 6093.

An open labyrinth joint should have a minimum gap width of 10 mm at all times.

5.4.4.5 Edge profile of panels

The edges of the stone panels may be grooved or rebated. As water might be held in grooves or corners of profiled edges, materials with which this water is likely to be held in contact should be resistant to the effects of wetting. Consideration should be given to the risk of high concentration saline solutions occurring during drying of water trapped in joints for buildings within 10 km of the sea or tidal estuaries.

If slots or grooves (kerfs and mortises) are cut into the upper horizontal edge of a panel, they should be such that water cannot be trapped in the slot or groove.

5.5 Cavity

5.5.1 General

NOTE The cavity is the void between the reverse of the rainscreen panels and the face of the backing wall.

The cavity should incorporate a clear air gap directly behind the rainscreen panels.

5.5.2 Pressure equalization

For a pressure-equalized rainscreen, the volume of air in any compartment, measured in cubic metres (m^3), should not exceed 80 times the total minimum free area of the open joints into the cavity, measured in square metres (m^2).

5.5.3 Air gap

The width of the clear air gap should be as follows, after the worst case accumulation of tolerances has been allowed for.

a) For a non-ventilated or drained-and-ventilated rainscreen with sealed or narrow joints, the air gap should be at least 25 mm deep.

b) For a drained-and-ventilated or pressure-equalized rainscreen with labyrinth or baffled joints, the air gap should be a minimum of 38 mm deep.

c) For a pressure-equalized rainscreen with open joints, the air gap should be a minimum of 50 mm deep.

5.5.4 Insulation

If the insulation layer is applied over the face of the backing wall, the insulation should be considered as an integral part of the cavity.

The insulation layer should be firmly fixed to the backing wall and properly supported over its entire area as the air in the cavity is exposed to significant pressure fluctuations and air currents, which can dislodge the insulation if not properly fixed.

Joints between adjacent pieces of insulation should be tight, with no gaps greater than 5 mm wide. If components such as framing or fixing brackets pass through the insulation layer, gaps around such components should be not more than 5 mm. If a tape is used to seal over such joints, it should be demonstrated that this tape has durability at least as great as that of the rainscreen panels.

5.5.5 Compartmentation

For a pressure-equalized rainscreen, the cavity should be divided into compartments. The compartment barriers should satisfy the following recommendations.

a) Horizontal compartment barriers should be used at every floor level.

b) Vertical compartment barriers should be used at centres of no greater than 6.0 m.

c) Vertical compartment barriers within 6.0 m of a building corner should be at centres of no greater than 1.5 m.

d) A vertical compartment barrier should be used no further than 300 mm from each building corner.

e) Each location where the alignment of the cladding changes by more than 15° in plan should be regarded as a building corner.

The compartment barriers should be permanently fixed in place, so that they are not dislodged by air pressure fluctuations within the cavity, nor by the flow of water down the back of the rainscreen.

The compartment barrier might be integrated into the design of the system, forming a baffle behind an open joint. In such instances, the gap between the compartment barrier and the reverse of the panels should be sufficient to satisfy the recommendations for the joint (e.g. 10 mm for an open joint) but it should not be significantly more than this so as to avoid compromising the principle of compartmentation.

If such an approach is taken, the material of the compartment barrier should be non-absorbent and resistant to the effects of wetting. For pressure-equalization calculations, one-half of the joint width should be associated with the compartment on each side of the barrier.

If a strip of some other material is used as a baffle behind the joint, the compartment barrier should be positioned hard-up against the reverse of the baffle.

If the compartment barrier does not align with a joint, it should be in contact with the reverse of the panels.

The compartment barriers should be such that the total air leakage through the backing wall and the barriers around the perimeter of any compartment does not exceed 10% of the air leakage through the rainscreen joints. For the purpose of this calculation, it should be assumed that all joints in the rainscreen that open into the compartment are open at all times, even if they are less than 10 mm in width.

Attention should be paid to the need for a breather membrane or vapour control layer in the cavity. The need for such a component should be determined in accordance with BS EN ISO 13788. However, the use of membrane layers in the cavity should be avoided, particularly on the face of the insulation layer, as they are liable to be exposed to significant pressure fluctuations and cannot be readily inspected for damage or degradation.

5.5.6 Breather membrane

NOTE A breather membrane can be used either on the external face of the insulation or, if insulation is not used or is resistant to the effects of wetting, on the face of the backing wall. The breather membrane can be a sheet material, or it can be a liquid-applied coating painted onto the surface of the backing wall. However, a liquid-applied coating is more likely to act as a vapour control layer.

Horizontal joints in the breather membrane should be arranged so that water which reaches the external surface of the breather membrane cannot run behind the membrane.

Joints in the breather membrane should overlap by at least 150 mm.

If the breather membrane is applied to the face of the backing wall, it should be applied before fixing brackets are secured to the backing wall. It should be noted, however, that if the breather membrane is too thick, there is a risk that the membrane will compress over time and allow the fixing brackets to settle.

If a breather membrane is applied over the face of an insulation layer, the breather membrane around any penetrations through the insulation layer should be secured and sealed. Particular attention should be paid to movement joints so that the breather membrane is not torn if structural movement occurs.

5.5.7 Vapour control layer

A vapour control layer should only be used if required by an analysis in accordance with BS EN ISO 13788. A vapour control layer should only be fitted on the warm side of the insulation layer.

NOTE 1 A coating of a bituminous or similar paint can be applied to the face of a masonry or concrete backing wall to act as a vapour control layer. As with a breather membrane, if the vapour control layer is too thick, there is a risk that the layer will compress over time and allow the fixing brackets to settle.

If framework or bracketry penetrates the vapour control layer, an analysis should be undertaken in accordance with BS EN ISO 10211 to demonstrate that thermal bridging due to the framework or bracketry will not give rise to condensation on the warm side of the vapour control layer.

Joints in the vapour control layer should be arranged so that water that reaches the external surface of the vapour control layer cannot run behind the layer.

NOTE 2 It is advisable to tape joints in the vapour control layer.

If the vapour control layer is an integral part of the insulation, the joints between insulation batts should be tightly butted and preferably taped over. The insulation should be checked to ensure it is installed the right way round.

Joints in a membrane vapour control layer should overlap by at least 150 mm. Particular attention should be paid to movement joints so that, if structural movement occurs, the vapour control layer is not torn.

Penetrations through the vapour control layer should be minimized.

5.6 Backing wall

*COMMENTARY ON **5.6***
The backing wall can take a variety of forms, e.g.:

a) pre-cast concrete panels, supported directly on the building's primary structural frame;

b) a reinforced concrete diaphragm wall, cast in situ;

c) blockwork or masonry walling constructed in situ and supported on the edge of the floor slab;

d) dry lining on studwork fixed directly to the floor slabs;

e) dry lining supported directly from the reverse of the same framework as the rainscreen panels.

The backing wall should be sufficiently strong to withstand all loads which might be applied to it. For a ventilated rainscreen system, the backing wall should be able to withstand the full design wind load, as well as point loads transmitted to it by the fixing system.

If the backing wall is supported on the edge of the floor slab, the backing wall should be able to accommodate differential movement between the floor slabs, and that the backing wall is not overturned by wind pressure.

If the backing wall is an existing masonry or concrete wall, the wall should be able to support the rainscreen system (testing might be needed to demonstrate this); pullout and proof load testing of the fixings into the existing wall is essential.

5.7 Cavity trays

Cavity trays should be provided at suitable intervals to intercept water draining down the back of the rainscreen and to collect and drain this water to the outside of the façade, typically at an open or free-draining horizontal joint.

Cavity trays should be continuous, and joints between consecutive lengths of cavity trays should be overlapped or sealed in accordance with the manufacturer's instructions.

NOTE Cavity trays can also be used as compartment barriers. Where vertical compartment barriers meet the cavity trays, gaps and openings might need to be sealed to ensure that pressure equalization is achieved.

If fire stops or smoke stops are to be used, it is recommended that they are located directly under the cavity trays to reduce the risk of wetting.

If cavity trays are not used as horizontal compartment barriers, then the upper surfaces of the compartment barriers should be sloped down and out to ensure that water drains to the outside and not towards the backing wall.

5.8 Copings, soffits and reveals

NOTE Penetrations through the rainscreen system, such as doors and windows, and natural terminations of the rainscreen system, such as occur at copings, require different treatments.

Surfaces which face upwards should not have open joints, even if they are labyrinthine or baffled. All joints in such surfaces should be sealed.

The interface between a door or window and the rainscreen layer might be constructed from stone panels, or from other materials such as metal pressings. These items might be secured to the building's primary structure or incorporated into any framing system which supports the stone panels; fixings to these components should satisfy the same recommendations as fixings to the stone panels in the rainscreen layer.

Consideration should be given to water run-off from upward-facing surfaces. Sealants in these locations might accumulate dirt, leading to staining of the façade directly beneath the ends of window sills and joints in copings. Features such as lips and drips should be used to separate the run-off flow from the vertical face of the wall.

Pattern staining at copings and sills should be avoided as follows.

a) Copings at roof level should be sloped so as to drain onto the roof covering or gutter.

b) Sills should be sloped or provided with an overhang or drip, if horizontal, to allow water to drain away from the façade.

Doors and windows should be sealed to the backing wall, not to the rainscreen. If the door or window is to be in the same plane as the face of the rainscreen panels, careful detailing should be undertaken so that air and water leakage do not occur at the penetration.

6 Performance

NOTE The various layers of a rainscreen façade contribute to the performance of the façade in different ways.

6.1 Structural performance

NOTE There are benefits to the use of larger, thinner, stone panels in rainscreen systems that justify the use of detailed structural analysis.

6.1.1 General

It should be demonstrated, either by calculation or testing, that:

a) the tensile bending stresses in the stone panels do not exceed the tensile strength of the stone, with a suitable factor of safety. In the worst case, it should be assumed that the panel is simply supported on two edges only, and the wind load should be calculated based on the overall face area of the panel. If it can be demonstrated that the rainscreen system is pressure-equalized, the wind load on the stone panel might be reduced to two-thirds of the design wind load;

b) the tensile stresses in the stone panels at the points of fixing do not exceed the tensile strength of the stone, with a suitable factor of safety. It should be assumed that loads on the panel are supported by no more than three of the fixings, unless it can be shown that the fixings will be installed such that the load is evenly distributed across all fixings;

c) the strength of each connection between the immediate fixing to the stone panel and the building's primary structure does not exceed the loads that are likely to be placed on the rainscreen system;

d) framing members do not buckle under the application of the design loads, for all spans and profiles used in the system;

e) framing members do not deflect more than is acceptable, under the loads that are likely to be placed on the rainscreen system;

f) the backing wall will not overturn or fail under the loads that are likely to be placed on the rainscreen system;

g) fixings into the backing wall will not pull out under the loads that are likely to be placed on the rainscreen system.

Particular attention should be paid to extreme conditions that only occur locally on the façade, e.g. ground floor treatments spanning a greater height than elsewhere on the building.

Previous test results should be used to demonstrate the suitability of a framing system subject to the following constraints.

1) The stiffness of the actual framing members should be no less than the stiffness of the framing members previously tested.

2) Rotation of the actual framing members at the points of fixing should be no greater than the rotation of the framing members previously tested.

3) The load to be transferred through each fixing should be no greater than for the system previously tested.

4) The weight of a stone panel should be no greater than for the system previously tested.

The backing wall should be capable of withstanding the full design wind load, plus any loads due to maintenance or temporary conditions during construction.

6.1.2 Serviceability loads and ultimate load factors

The following basic serviceability loads should be calculated for the façade:

a) characteristic wind load:w_e in accordance with BS EN 1991-1-4;

b) characteristic dead load: G_k in accordance with BS 648;

c) characteristic imposed load: Q_k in accordance with BS EN 1991-1-1 and BS EN 1991-1-3.

For serviceability purposes these loads may be used directly to determine the deformation and deflection of the stone panels and support frame. The system should not deflect beyond acceptable limits nor exhibit excessive permanent deformation (see **6.1.5**) when the maximum serviceability design load is applied.

NOTE 1 This can be demonstrated by testing or calculation.

Stone is a brittle material which fails if overstressed and, therefore, the design of the panels and fixings should be based on the ultimate limit state. The following load factors, γ_k, should be used when calculating ultimate design loads:

1) wind load factor: 1.4;

2) dead load factor: 1.4;

3) imposed load factor: 1.6.

Loads should be applied in the correct directions, i.e. wind loads typically act perpendicular to the face of the system, whilst dead loads act vertically and imposed loads act in various directions depending upon the source of the load and point of load application.

NOTE 2 It may be assumed that the worst case imposed load will not occur concurrently with the worst case wind load.

6.1.3 Safety loads

It should be demonstrated that neither the rainscreen panels nor the connecting elements of the system will fail when subjected to a load equal to 1.5 times the maximum serviceability design load.

6.1.4 Stone factors of safety

The material factor of safety for natural stone is generally higher than for other materials for several reasons and these should be taken into account:

a) stone is a natural material and not subject to the same degree of control during its creation that can be applied to factory manufactured products;

b) stone is a brittle material and cannot yield to accommodate localized high stresses (i.e. if it is overstressed it breaks);

c) stone is liable to attack/degradation by atmospheric pollutants and this can reduce the strength of stone over time;

d) stone can contain flaws or inclusions which weaken the material, and there is no guarantee that a relatively limited programme of testing will include pieces of stone containing one of these defects;

e) stone can crack over time (microcracks) as a result of thermal/moisture cycling or cyclic wind loads, and this reduces the strength of the stone;

f) the panel edges can be damaged during cutting, installation or in service, and this weakens the stone (the edges of the panel are where the highest stresses often occur);

g) the stone that was tested is not necessarily representative of the stone that is to be put on the building (stone for testing is typically taken from the first block(s) to be extracted, rather than from every block used on the project).

Bending tests in accordance with BS EN 13161 (constant moment) should be requested in order to determine the strength of the stone.

COMMENTARY ON ***6.1.4***
The stone needs to be tested at or near the intended project thickness, with the stone in the same orientation (with regard to bedding/rift) and with the same finishes intended to be used on the project. A minimum of ten specimens need to be tested.

If the test is undertaken with dry stone, and the mean strength calculated, the factor of safety based on that mean strength, and the ultimate design load, ought to be 5.0, regardless of stone type.

Alternatively, if additional tests are undertaken with saturated stone (minimum ten specimens) and the wet mean strength calculated, the factor of safety may be reduced to 4.3, based on the ultimate design load, regardless of stone type.

Finally, if tests are undertaken with a set of at least ten samples in each of the dry and saturated states, and the lower expected value for each set is calculated in accordance with BS EN 13161:2008, Annex A, the factor of safety for use with the lowest lower expected value and the ultimate design load may be taken from Table 1 based on the specific stone type.

Table 1 **Stone type factors of safety**

Stone	Factor of safety
Granite	2.0
Sandstone	3.0
Quartzite	2.0
Slate	2.0
Limestone	3.0
Marble	2.5
Travertine	2.5

6.1.5 Deflection limits

Permanent deformation and deflection of any framing system should be kept within acceptable limits. At both positive and negative applications of the serviceability design wind pressure, the limiting deflections shown in Table 2 should be assumed.

It should be demonstrated that permanent deformation will not exceed 1/500 of the span of any component when the serviceability design loads are applied.

Table 2 **Deflection limits**

Framing system	Deflection limit [A)]
Individual rainscreen stone panels	*L*/360 or 3 mm, whichever is the lesser, where *L* is the span between points of support, unless more restrictive limits are set by the panel supplier
Masonry or concrete backing walls	*L*/360 or 10 mm, whichever is the lesser, where *L* is the span between points of support
Framing members generally	*L*/200 or 20 mm, whichever is the lesser, where *L* is the span between points of support
Framing members that also support double glazing	*L*/175 or 15 mm, whichever is the lesser, where *L* is the length of the edge of the pane, unless more restrictive limits are set by the unit manufacturer
Framing members that also support single glazing	*L*/125 or 15 mm, whichever is the lesser, where *L* is the length of the edge of the pane
Surfaces or framing members to which brittle materials, such as plasterboard, are to be fixed	*L*/360, where *L* is the span between points of fixing of the brittle material

A) It is assumed that there are four symmetrically arranged fixings on a typical rectangular panel. If the panel is non-rectangular, or if there are more than four fixings, or if the fixings are asymmetrically arranged, the façade designer should demonstrate that deformation of the framing system will not induce additional bending or fixing stresses in the stone.

6.1.6 Cyclic wind loading

For systems in which the rainscreen panels are supported on a framing system that also supports the backing wall or has an integral backing wall, it might be appropriate for cyclic wind loading tests to be carried out. Where these tests are deemed necessary, it should be specified that:

a) the design wind pressure is to be applied in the following sequence to demonstrate that there is no reduction in performance:
   1) 90% serviceability wind load: 1 cycle;
   2) 40% serviceability wind load: 960 cycles;
   3) 60% serviceability wind load: 60 cycles;
   4) 50% serviceability wind load: 240 cycles;
   5) 80% serviceability wind load: 5 cycles;
   6) 70% serviceability wind load: 14 cycles;

b) this sequence is to be applied a total of five times, followed by a single application of the design serviceability (100%) wind load;

c) for the purpose of this testing, all components are to be included in the test sample;

d) following completion of this test cycle, the rainscreen panels are to be removed and the airtightness and watertightness of the backing wall re-tested.

If testing demonstrates that the cyclic loading has not reduced the watertightness rating, and that the air leakage through the backing wall has not increased by more than 10%, the performance may be considered acceptable.

6.2 Weathertightness

6.2.1 General

If the backing wall meets the specified recommendations for weathertightness, the performance of the rainscreen layer is not relevant; it is therefore sufficient to demonstrate that the backing wall satisfies all recommendations for weathertightness of the ventilated rainscreen system, as described in **6.2.2** and **6.2.3**; if this is done, there is no need to demonstrate that the remainder of the system satisfies those recommendations.

*COMMENTARY ON **6.2.1***
A ventilated rainscreen cladding system can only be reliably tested as a whole if a dynamic pressure is applied to the face of the wall. In most cases, the pressure needs to be applied over the whole of the face of the wall over the compartment under test.

This is not generally possible using the exact dynamic test for watertightness (see DD ENV 13050), which applies a much more localized pressure to the face of the test sample. The use of this test on a ventilated rainscreen wall system is likely to result in unrealistic gross water penetration, due to substantial differential pressure variations over the face of the compartment.

6.2.2 Airtightness of the backing wall

The backing wall should be airtight and testing in accordance with BS EN 12153 should be requested to establish the airtightness. It should be specified that, for the purpose of this test:

a) all elements of the system with the exception of the rainscreen panels are to be fitted;

b) the test is to be undertaken at both positive and negative applications of the test pressure;

c) the air leakage is to be taken as the average value of the magnitude of the air leakage for the positive and negative pressure applications.

6.2.3 Watertightness of the backing wall

The backing wall should be watertight and testing in accordance with BS EN 12155 should be requested to establish the watertightness (i.e. by demonstrating that water penetration does not occur when the backing wall is tested at the required test pressure). It should be specified that, for the purpose of this test, all elements of the system with the exception of the rainscreen panels are to be fitted.

6.3 Thermal performance

The thermal performance of the wall should be determined in accordance with BS EN ISO 13789, BS EN ISO 6946 and BS EN ISO 10211.

For a ventilated rainscreen system, the air gap should be assumed to be a well-ventilated airspace and the rainscreen layer should be disregarded when calculating the overall heat loss through the wall in accordance with BS EN ISO 6946.

Penetrations through the insulation layer should be taken into account when calculating the thermal performance of the system. If the façade designer assumes that small voids will be filled with insulation in order to meet the specified thermal performance recommendations, this should be noted on the design drawings and confirmed that the insulation is fitted correctly.

6.4 Acoustic performance

Any requirement for the rainscreen system to provide acoustic performance should be stated by the specifier.

NOTE A ventilated rainscreen system is likely to provide a lower level of acoustic performance than an unventilated cladding system.

If the backing wall is designed so as to achieve the desired acoustic performance, the possibility of noise being transmitted along the cavity, particularly around door and window openings, should be taken into account.

6.5 Fire performance

Fire performance should be in accordance with BS 8298-1.

When detailing penetrations such as doors and windows, suitable fire and smoke stopping should be incorporated, if necessary.

NOTE Compartment barriers and baffles might not act as fire or smoke stops if there are small gaps between the barriers and the reverse of the panels or framing system.

A potential problem with open-jointed rainscreen systems at low level is that a fire could be started against the wall, which could result in the spread of smoke and flame over a considerable area and, therefore, consideration should be given to such events and the possibility of using a different type of façade system at low levels.

6.6 Impact resistance

The risk of impact on the surface of the cladding system should be considered at the design stage and the recommendations of BS 8298-1:2010, **6.14** should be followed.

6.7 Electrical earthing and lightning protection

Unless otherwise specified, a metal framing system should be designed in accordance with BS 7671:2008, Chapter **41**.

NOTE Guidance on lightning protection is given in the BS EN 62305 series.

7 Workmanship on site

*COMMENTARY ON CLAUSE **7***
*Poor workmanship can affect the performance of a ventilated rainscreen system. Various factors are described in **7.1**, **7.2**, **7.3** and **7.4**.*

7.1 Drawings

NOTE Generic drawings can be provided, showing typical details, rather than providing detailed drawings for all locations.

Drawings should show all information that is likely to be required by the installer. For example, drawings should include:

a) setting out of datum lines;

b) size and type of panel at each position;

c) positions of brackets and framework;

d) type of bracket at each location, where different types are available;

e) types of fastener or anchor at each location, and fixing torque where appropriate;

f) tolerances on fixing position;

g) joint widths, including allowable tolerances;

h) joint seal types, including backer materials where needed;

i) insulation types;

j) type and location of membranes, and need for lapping at joins;

k) need for taping and sealing around penetrations;

7.2 Structural issues

Fixings should be made straight and true. Fasteners or anchors should not be installed in such a way that they bend when tightened and the heads of fasteners should bear evenly on surfaces.

Structural calculations should be provided to show that the thickness of packers does not cause design loads (as provided by the fixing manufacturer) on fasteners or anchors to be exceeded.

Packers and shims should be:

a) made of a suitable material (typically metal) and materials which can creep (e.g. some plastics) or rot (e.g. timber) should not be used in structural connections;

b) evenly distributed under the item which is being packed off;

c) shaped so as to be held in place by the fastener or anchor;

d) if stacked, evenly stacked and only placed against a flat surface.

Washers should be of a type appropriate to the fastener or anchor. Washers should not be stacked beyond limits set by the manufacturer.

If self-drilling fasteners are used and later removed, the same hole should not be used for re-fixing. In particular fasteners into thin layers should not be over tightened.

Other structural components should not be cut or drilled on site unless it is shown that the modified component still satisfies the structural calculations. Particular care should be taken where site modification is likely to cut through protective finishes.

Structural components that are damaged should not be used unless it can be shown by calculation or otherwise that the damage will not reduce the load-carrying capacity of the component below the allowable factors of safety.

Stone panels should never be cut to size on site. Site cutting or drilling for other reasons should be avoided wherever possible. If the need to cut or drill on site arises, this should be referred to the façade designer. Cutting or drilling should always be to the dimensions shown on the design drawings as overcutting or overdrilling might weaken the system. If site tolerances are such that it is not possible to fit the system in accordance with the design drawings, this should be referred to the designer and approval sought before continuing with the installation.

7.3 Materials issues

All materials should be stored and used in accordance with the manufacturer's recommendations. Materials should generally be stored in a clean, dry, dust-free environment, away from extremes of temperature or solar radiation. When applying materials such as sealants and adhesives the surfaces to which they are applied should clean, dry and at a suitable temperature.

All materials should be as shown on drawings, and materials or components should not be substituted unless approved by the façade designer. If materials or components are substituted, the alternative materials should be clearly marked on the as-built drawings.

Prior to use, materials such as sealants and adhesives should be checked for an expiry date, and out-of-date materials disposed of in accordance with the manufacturer's recommendations.

Components that are damaged during installation should not be used unless it can be shown by the designer either that the damage will not affect the performance of the system/component, or that the item can be repaired in a manner that is durable for the life of the cladding system.

7.4 Protection of works

Works should be suitably protected until they are completed (e.g. where scaffolding is shared with other trades this might include the use of barriers or boards to prevent accidental contact with the stone panels).

Where the framing system requires the fixings to the stone panels to be secured with a sealant, resin or grout, the stone panels should be secured in place until curing of these materials has taken place. If the stone panels are disturbed before the sealant, resin or grout has achieved a suitable level of cure, the stone panel(s) should be removed and re-set.

Bibliography

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

BS EN 62305-1, *Protection against lightning*

BS EN ISO 9000 (series), *Quality management systems* [3)]

DD ENV 13050, *Curtain walling – Watertightness – Laboratory test under dynamic condition of air pressure and water spray*

3) In the Foreword only.

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