

Cladding Stones

Definition

“A facing of thin stone - limestone, sandstone, slate, marble or granite – additional to the required statutory construction, but not so bonded to that construction as to exert common action under load”.

1). Division.

Natural stone has been used by man for construction purposes for several thousand years. The main groups of stone of interest can be divided into 3 geological groups:

- Limestone and Sandstone – Sedimentary Rocks,
- Slate and Marble – Metamorphic Rocks,
- Granite – An Igneous Rock.

2). Advantage of natural stone.

Benefits of use natural stone cladding:

- durable,
- aesthetically pleasing,
- relatively maintenance free,
- low carbon footprint compare to other materials.

3). The design phase.

The decision on the type of cladding needs to be made early in the design process and will be determined by the function of the cladding, the size, height and location of the project, the type of structure and the programme.

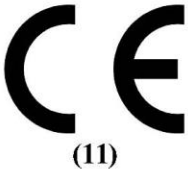
4). Selection of stone.

The selection of stones to be used on the project should be made from Indicative Samples. Small samples can show the typical colour and texture, but cannot show the natural variations that are presented in all stones. The stone selection should be confirmed with an inspection of various building (case studies) built using the same and visit to the quarry to view the natural faces and the Quarry Range Panels.

The designer should be aware of the recommendation lead-in period for the supply of stonework cladding.

5). CE Certificates.

CE marking provides a legal confirmation to the client/architect that the product is suitable to be placed on the market. Existing in its present form since 1993, the CE marking is a key indicator of a product's compliance with EU legislation and enables the free movement of products within the European market. By affixing the CE marking on a product, a manufacturer is declaring, at their sole responsibility, conformity with all of the legal requirements to achieve CE marking and therefore ensuring validity for that product to be sold throughout the European Economic Area.

		
Number of the reference standards	Products	Final Applications
UNE-EN 1341:2002	Slabs of natural stone	For external applications and pavement finishing intended for paving pedestrian and vehicles passing areas outdoors.
UNE-EN 1342:2003	Setts of natural stone	For external applications and pavement finishing intended for paving pedestrian and vehicles passing areas outdoors
UNE-EN 1343:2003	Kerbs of natural stone	For external applications and pavement finishing intended for paving pedestrian and vehicles passing areas outdoors.
UNE-EN 1469:2005	Natural stone slabs for cladding of walls and vaults	Finishing of both internal and external vaults and wall cladding.
UNE-EN 12057:2005	- Natural stone modular tiles for pavements and stairs. - Natural stone modular tiles for cladding walls and vault	- Finishing of internal pavements including those installations for public transportation. - Finishing of external pavements intended for pedestrian and vehicle passing areas - External or internal finishgin of walls or vaults
UNE-EN 12058:2005	Slabs of natural stone for floors and stairs	- Internal pavement finishing. - External pavement finishing
Material: Trade Name: GRANITO AMARELLO SAN MARTINHO Quarrying place: Campinhos (Monção – Portugal)		
CHARACTERISTICS	DECLARED VALUES	TEST METHOD
Aspect	Yellowish colored rock-medium to coarse grain size - granite texture	VISUAL
Petrographic description	Biotite granite	UNE-EN 12407:2007
Bulk density (Kg/m^3) – Open porosity (%)	2610 – 0,9	UNE-EN 1936:2007
Reaction to fire (Class)	A1	No test (Decisión 96/603/EC)
Flexural strength		
Average value (MPa)	12	UNE-EN 12372:2007
Standard deviation (MPa)	0,5	
Water absorption at atmosph. pressure Average value (%)	0,3	UNE-EN 13755:2008
Anchorage strength		
Average value of the breaking strength (N)	2300	UNE-EN 13364:2002
Water steam permeability	NPD	UNE-EN 12524:2000
Thermal shock resistance		
Average value of mass variation (%)	-0,04	UNE-EN 14066:2003
Average variation value of the dynamic E-modulus (%)	28,9	
Slipping resistance		
Polish-finished		
Dry USRV	73	UNE-EN 14231:2004
Wet USRV	20	
Home-finished		
Dry USRV	67	
Wet USRV	31	
Icy resistance (Average flexural strength reduction)		
After 48 cycles (%)	10,3	UNE-EN 12371:2011
After 12 cycles (%)	3,5	
Abrasion resistance (Average value of the print width) (mm)	16,3	UNE-EN 14157:2005
Compressive strength		
Average value (MPa)	152	UNE-EN 1926:2007
Standard deviation (MPa)	8	

CE-AS

Revision date: 21/02/2012

Pavestone Unipessoal, lda. SEDE SOCIAL: Estrada dos Arcos, Edif. Mario Gomes - Bloco B - 1º esq. - 4950 Monção. CAPITAL SOCIAL: 400.000 - C.R.C. MONÇÃO Nº 507.928.580
CONTRIBUINTE Nº 507.928.580

Table 1. Typical CE Certificate

6). Stone thickness.

The maximum dry weight of cladding stones ranges from 2500 kg/m³ for limestone to 2750 kg/m³ for granite. Therefore, for general guidance purposes only a figure of 3000 kg/m³ can be used to calculate the maximum likely load to be carried – BS 8298: 2000.

In order to derive the benefit from “designed” thickness of the stone, it is vital that the designer makes an early selection of the stone and then designs the building to suit the stone. The overall cost saving for reducing the thickness could be significant, not only for the stone but also the structure itself. The factors that effect the calculation for the thickness are:

- Stone strength,
- Panel size,
- Wind loadings,
- Fixing location in the stone,
- Type of fixing.

It is also necessary to consider the strength of the stone around the fixings. The breaking load at the fixings will be dependent on the area of the panel, the estimated wind loading and the stones strength.

Maximum masses per square metre of cladding stones				
Stone	20mm thick	40mm thick	50mm thick	75mm thick
	kg	kg	kg	kg
Granite, Marbles, Hard Limestones, Slates and Quartzites	60	120	*	*
Limestones and Sandstones	*	*	150	225
* These stones are not normally used as cladding at these thicknesses (see table 3)				
E.g. – 9 m ² of Granite 40mm thick = 1 ton.				

Table 2. Maximum Masses per Square Metre of Stone – BS 8298: 2000

Table. Thickness of stone and depth of slot for corbel plate (see figure 1)

		Stone thickness*				Minimum thickness of stone behind a cramp mortice (t)				Minimum depth of slot for a corbel plate (d)			
Stone type	G Mw SL Q	T LsH	Mb	Ls Ss	G Mw SL Q	T LsH	Mb	Ls Ss	G Mw SL Q	T LsH	Mb	Ls Ss	
Stone location	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	
Cladding (external)													
Less than 3.7 m above ground or floor level and continuously supported (inc. fascias)	20	20	20	50	7	7	7½	25§	Not applicable				
Fascias less than 3.7 m above ground or floor level	30	30	NA	50	12	12	NA	25§	20	20	NA	25§	
More than 3.7 m above ground or floor level (inc. fascias)	40	40	NA	75	20	20	NA	37§	25	25	NA	37§	
Soffits (including inclined soffits)	40	40	NA	75	20	20	NA	37§	Not applicable				
Sills, coping and supported reveals	30	30	NA	50	12	12	NA	25§	Not applicable				
Stone faced concrete units	30	30	NA	50	Not applicable				Not applicable				
Lining (internal)													
Less than 7 m above ground or floor level and continuously supported (inc. fascias) +	20	20	20	50	7	7	7½	25§	Not applicable				
Less than 7 m but more than 3.7 m above ground or floor level on corbles in slots (inc. fascias)	30	30	NA	50	12	12	NA	25§	20	20	NA	25§	
More than 7 m above ground or floor level (incl. fascias)	30	40	NA	75	12	20	NA	37§	20	25	NA	37§	
Soffits (including inclined soffits)	40	40	NA	75	20	20	NA	37§	Not applicable				
Abbreviations													
G Granite				Q Quartzites									
Ls Limestones (e.g. Portland, Bath, Clipsham)				SL Slates (those unlikely to de-laminate)									
LsH Hard Limestones (e.g. Roman stone)				Ss Sandstones (e.g. York, Northumberland, Scottish)									
Mb Brecciated marbles (most coloured marbles)				T Travertines									
Mw White marbles													
* See 28.2.2 for permissible deviations.													
+ Internal cladding between 3.7 m and 7 m in height in a continuous face should have an intermediate corbel course.													
½ Brecciated marbles may need to be reinforced with block liners (see 20.7) but in assessing the minimum thickness of stone behind a cramp mortice the thickness of the block liner should be ignored.													
§ Half thickness if stone is more than 75 mm thick.													
The figures in the table apply to soffit stones not exceeding 900 x 600mm. If stone of a greater size are required consideration should be given to using some face fixings and/or additional fixings in the length and/or increased thickness. Internal soffit stone not less than 1.2 m and not more than 3.7 m above floor level, continuously supported at reveals may be 20mm thick for G, Q, SL, T, LsH, Mw and 50mm for Ls and Ss.													

Table 3. Thickness of Stone – BS 8298: 2000

7). Tolerance in Stone.

The manufacturing tolerance on the thickness and face dimensions of stones is set out in BS 8298: 2000 and confirms to the European Standard BSEN 1469.

- a). Units 50mm thick or less: the length and height dimensions should not vary from those specified by more than $\pm 2\text{mm}$.
- b). Units over 50mm thick: the length and height dimensions should not vary from those specified by more than $\pm 3\text{mm}$ in 900mm.

8). Design of Fixing Systems.

The objective is to achieve safe and reliable fixing of the cladding and full consideration at an early stage of the design work is essential. Fixings must be capable of three-dimensional adjustment to accommodate construction tolerances.

a). Dead Loads (Permanent)

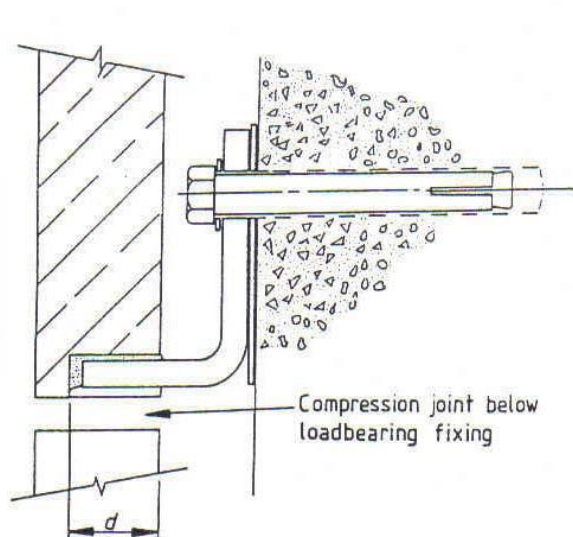
The actual weight of the supported stonework, which can be conservatively assessed using a density of 3 tones per cubic meter. In some cases the stone may be offset from the centre of support and the dead load will then act eccentrically on the fixings.

b). Applied Loads (Transient)

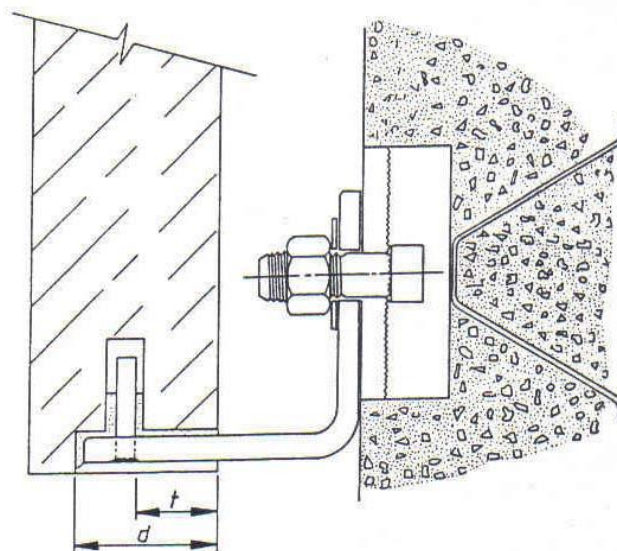
Caused by wind pressure and suction, window cleaning equipment, thermal and structural movements, etc. These loads will need to be assessed by a Structural Engineer.

9). Details of Fixing Types.

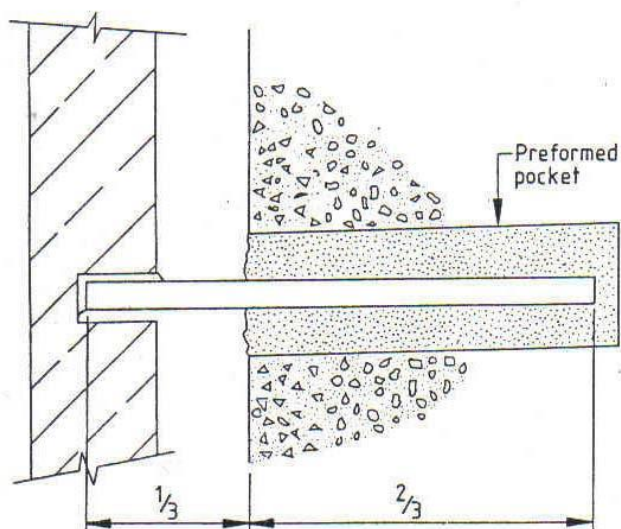
Important note: *Fixings must be produced from stainless steel or non-ferrous metal, must be of sufficient size and strength to resist the relevant forces and must be readily available to meet the construction programme.*



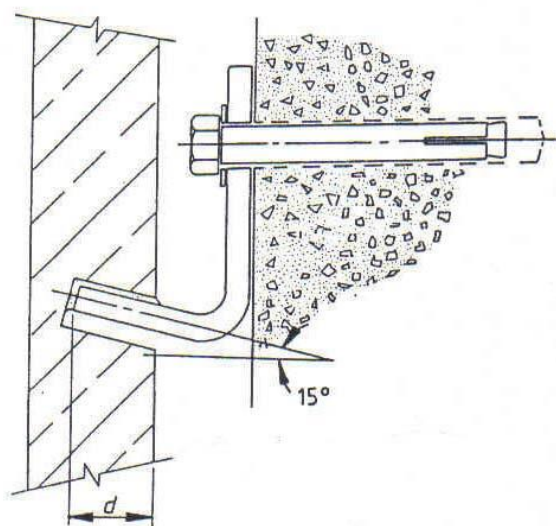
(a) Bottom edge support



(b) Bottom edge support with restraint



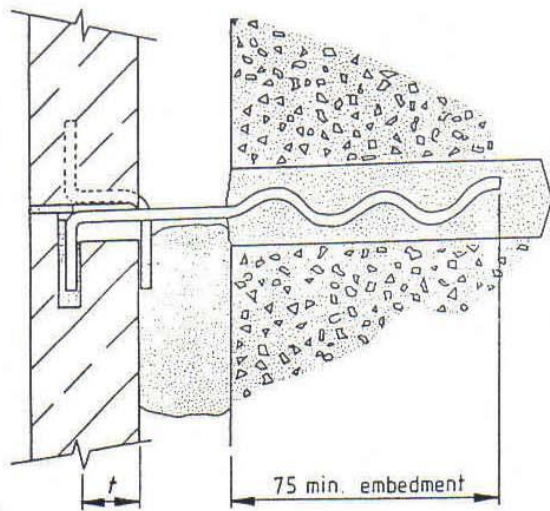
(c) Support by a corbel plate in slot



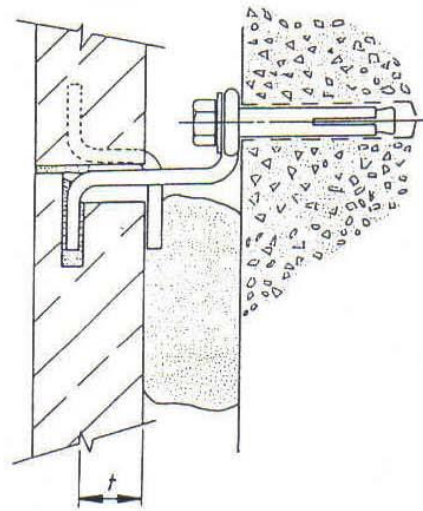
(d) Support by corbel plate in a slot with restraint

NOTE: t is the minimum thickness of stone behind cramp mortice
 d is the minimum depth of slot for a corbel plate

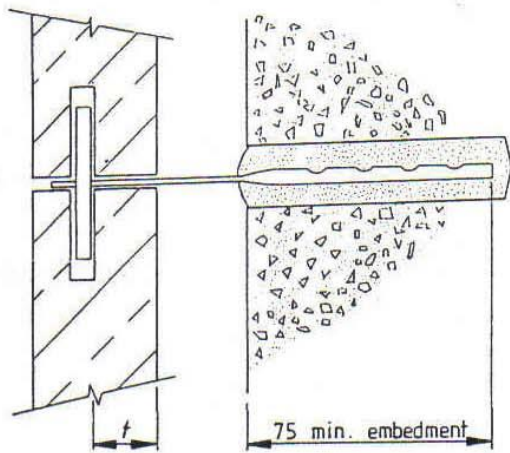
Fig 1. Details of typical loadbearing fixings.



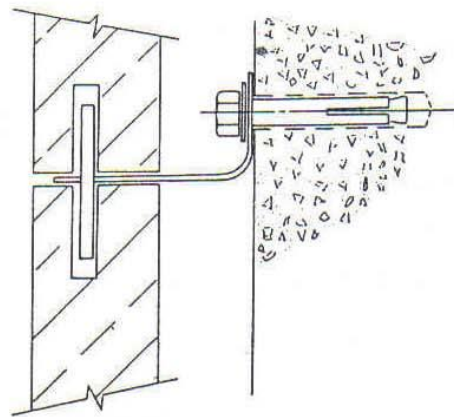
(a) Grouted wire ties



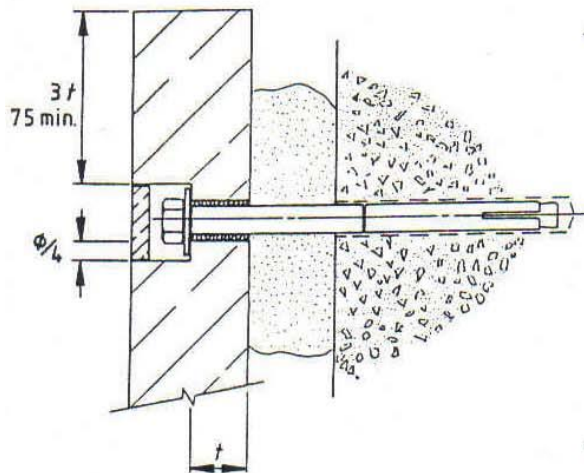
(b) Bolted wire ties



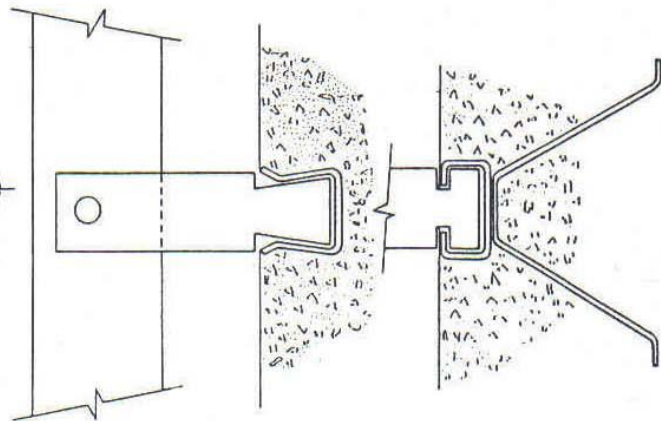
(c) Grouted cramp and dowel



(d) Bolted cramp and dowel



(e) Face fixing



(f) Alternative cast-in slot and cramp

NOTE: t is the minimum thickness of stone behind cramp mortice

All dimensions are in millimetres.

Fig 2. Details of typical restraint fixings.

10). Traditional Handset Cladding.

Traditional hand fixed cladding still dominates the use of typical granite, limestone and sandstone cladding, particularly for the medium and smaller projects. The traditional hand fixed cladding system typically carries the load of the cladding to a load bearing fixing situated at the floor plate. The stones above are simply restrained using Restraint fixings.

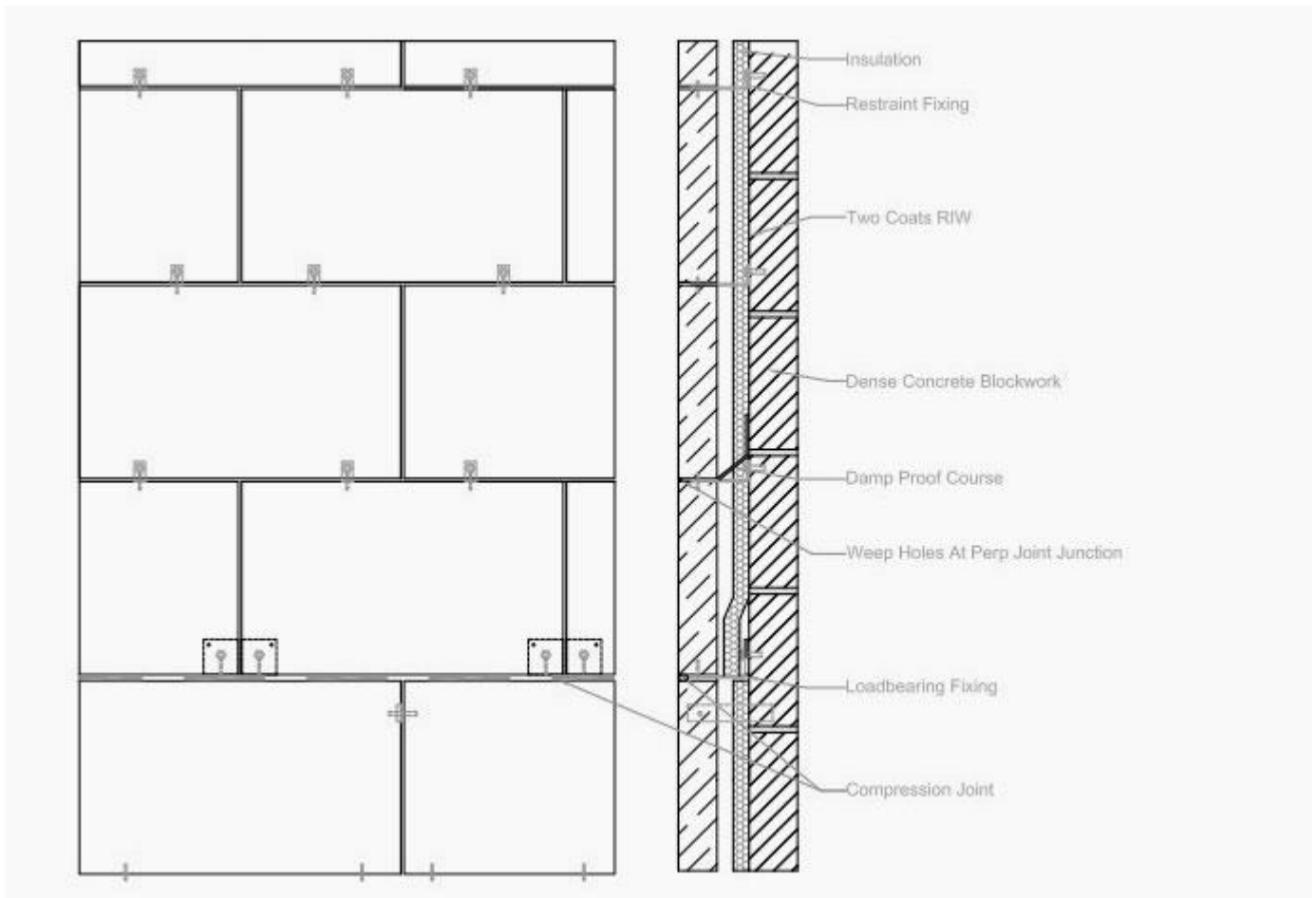


Fig 3. Traditional Cladding

10 a). Fixings.

The positioning and type of loadbearing and restraint fixings will be determined by a number of factors including stone thickness calculation, the location of the movement joints and the actual structure of the building – see detail fig. 1 & 2.

10 b). Movement Joints.

The structure of the building and the stone cladding will be subject to movement. The movement will be initially due to shrinkage and/or elastic deformation under load. Ongoing movement will occur due to differential thermal movement of the structure, the fixings and the stone, the moisture of the stone and movement from wind loading. It is recommended that the Structural Engineer/Designer sets out calculations showing the effects of these various movements and ensure that the cladding can accommodate them.

10 c). Compression Joints.

Compression joints are horizontal movement joints and are designed to accept vertical movement of the structure. They are normally situated at each floor level immediately under the course supported by the load bearing fixings.

10 d). Weep Holes.

Weep holes will need to be designed where trapped moisture accumulates at cavity trays and at the D.P.C. levels.

10 e). Expansion Joints.

Expansion joints are vertical movement joints. The spacing and the widths of these joints need to be designed to accommodate anticipated movement.

NORMAL MINIMUM WIDTH OF JOINTS – BS 8298		
STONE	JOINT MATERIAL	
	MORTAR (mm)	SEALANT (mm)
GRANITE, MARBLE, HARD LIMESTONE AND SLATE	3	5*
SLATE WITH RIVEN FINISH	7	5
SOFT LIMESTONE AND SANDSTONE	5	5
* Below first floor level sealant can be used at a minimum of 3mm		

Table 4. Widths of Joints – BS 8298

10 f). Sealants.

All movement joints need to be filled with a sealant, specially designed for stone use. Recommended product – Soudal – Silirub MA. (attached info).

10 g). Mortars.

The manufacture tolerances as set out in BS 8298 allow for typically 5mm (± 1.5 mm) joints. The maximum width of a mortar joints is 13mm, but sealant filled movement joint can be up to 30mm wide.

Cement Lime Mortars. The recommended mixes are set out below:

EXPOSURE	White Portland Cement	Hydrated Lime	Stone Dust/Sand
SEVERE	1	1	5 to 6
NORMAL	1	2	8 to 9

Table 5. Mixes for Mortar Joints – BS 8298

10 h). Cavities.

The cavity between the stone cladding and the backing structure will incorporate an air gap, insulation and breather membrane. The cavity will need to be sufficiently wide to allow for free draining of any trapped moisture allows for insulation, accommodation of the fixings, bolt heads, etc. and to take up all structural tolerances. The minimum width of the air gap should not be less than 10mm after all the construction tolerances have been included, but please note that a cavity width greater than 100mm may need supplementary framework to support the stone.

10 i). Cavity Trays.

The cavity trays and the DPC should be formed from materials that will not degrade and stain the stonework. The cavity trays need to be laced at appropriate points to direct moisture out of the cavity where it could degrade the insulation or cause dampness to the backing structure.

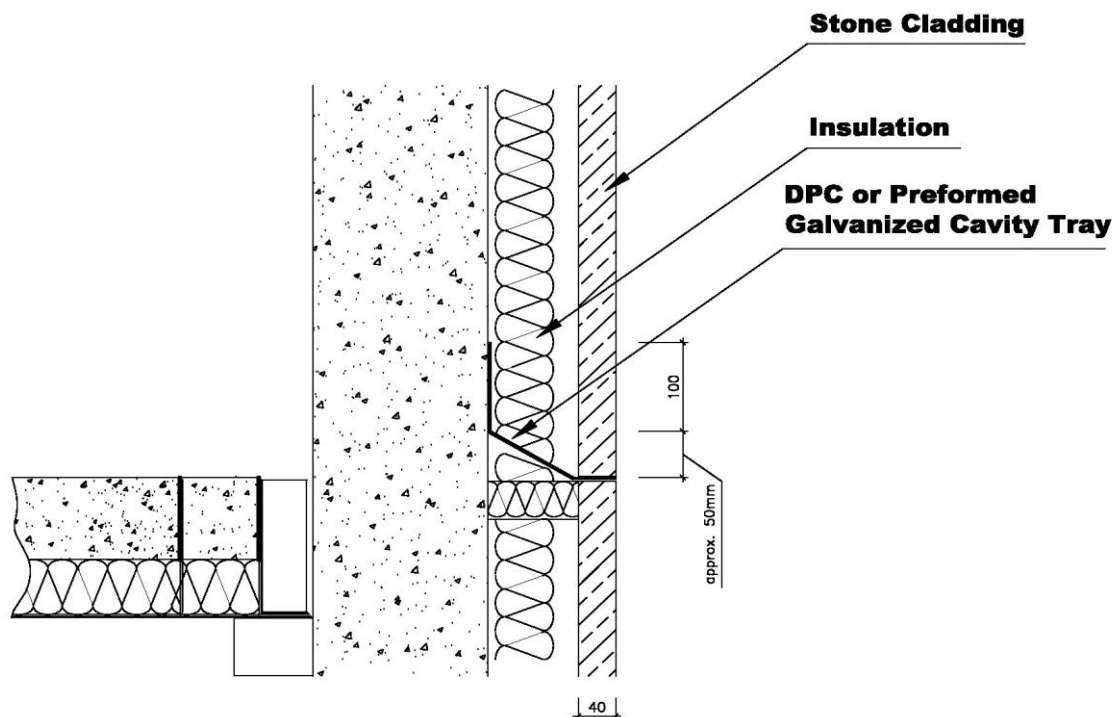


Fig 4. Cavity Trays Typical Detail - Section

10 j). Damp Proof Course – DPC.

A damp-proof course (often abbreviated to DPC) is a horizontal barrier (thin plastic strip) in a wall designed to prevent moisture rising through the structure by capillary action – rising damp.

11). Rainscreen Cladding

Ventilated rainscreen cladding is a system of cladding which the stone panels are used as part of a system that shields the majority of the supporting structure from direct rainfall. It combines a cavity and drainage system behind the panels to remove any moisture that gets past the rainscreen panels. There are two types of rainscreen panels:

- **Pressure – Equalised**

The cavity behind the panels is divided into compartments to generate pressure to impede the ingress of water through the open joints.

- **Drained-and-Ventilated**

The open joints between the stones permits air movement, thereby encouraging the drying out of moisture that gets through the joints.

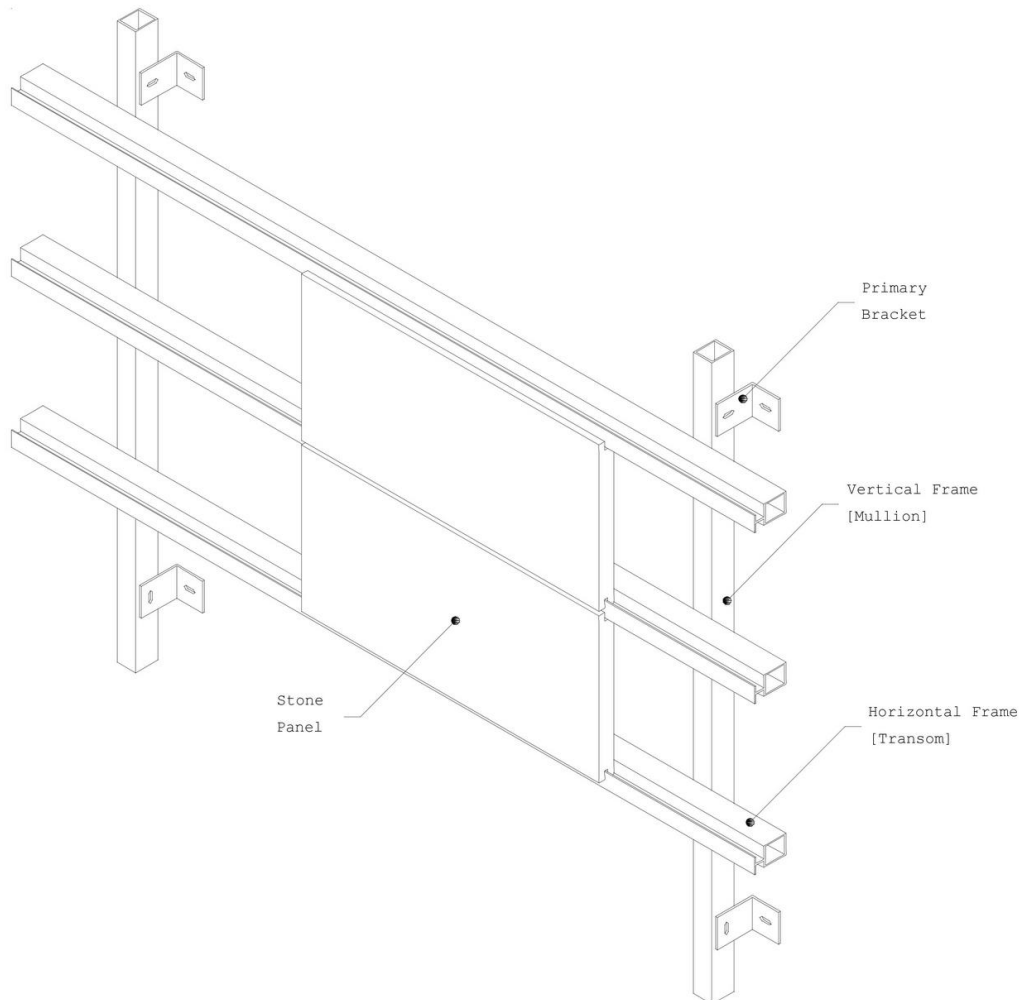


Fig 5. Rainscreen Cladding System

11 a). Fixings.

The individual stones can either be fixed to a backing wall or more typical to a framing system comprising of a grid of vertical and horizontal s/steel/aluminium profiles. The fixings to the stone will normally have combined load bearing and restraint capabilities. They can be brackets recessed into the joints of the stones or undercut anchors in the back of the stones. There are a number of different systems that offer differing advantages and disadvantages to the cladding designer.

11 b). Ultra Thin Cladding.

There are a number of different methods of attaching very thin stone onto a strengthening substrate, these include the honeycomb aluminium, ceramic etc. These systems can reduce the weight of stone cladding significantly thereby saving structural costs, but the cladding itself is typically more expensive than just natural stone cladding.

11 c). Movement Joints.

The designer needs to be aware of the various movements: thermal, dead and live loads, settlement, moisture and wind loading, between the structure, the framing system and the individual stones.

Joints in a rainscreen panel system are designed to permit air circulate behind the panel and to allow moisture to drain from the cavity. In most projects, all the joints will be open, but some joints can be filled with an appropriate sealant if required. If a sealant is used it is important to ensure that it has a good service life, will match the colour of the stone and will not cause staining of the stone. A primer may be necessary. The joint width needs to be carefully controlled to ensure that it is wide enough to be classed as “open” at all times. An open joint is normally classed as a minimum of 10mm and will allow free draining of water.

11 d). Cavities.

The cavity between the stone and the backing structure will incorporate an air gap, insulation and breather membrane. The cavity may also be divided into compartments if a pressure-equalised system is being designated, ensuring that the compartment's air volume is correctly proportionate to the open joints.

12). Liquid Waterproofing System – Blackjack.

It is a continuous seamless waterproofing system for horizontal or vertical external surfaces. Can be used on all types of substrates and may be used on both new and existing surfaces (facades, basements, water collectors, porous surfaces and bituminous layers).

Main properties:

- Waterproof, permits perspiration of the surface, strongly adhered to the surface,
- Flexible even at extreme temperatures (-25°C to +80 °C),
- Non-toxic and self-extinguishing,
- Fungicide and anti-mildew,
- Smooth and finely textured paste, easy to apply,
- UV Stable colours for exteriors.

13). EPDM.

The EPDM membrane is a waterproofing vulcanized rubber sheet, for all kinds of waterproofing applications (facades, roofs, pools, ponds, etc.)

EPDM rubber is a lightweight material with enviable durability outdoors estimated at approx. 50 years, which implies important energy saving both on manufacturer and during its useful life cycle, with fewer replacements.

Main properties:

- Permanent elasticity from -40°C to $+120^{\circ}\text{C}$.
- Ozone and UV radiation resistance.
- Excellent thermal and dimensional stability.
- Easy and fast to install.

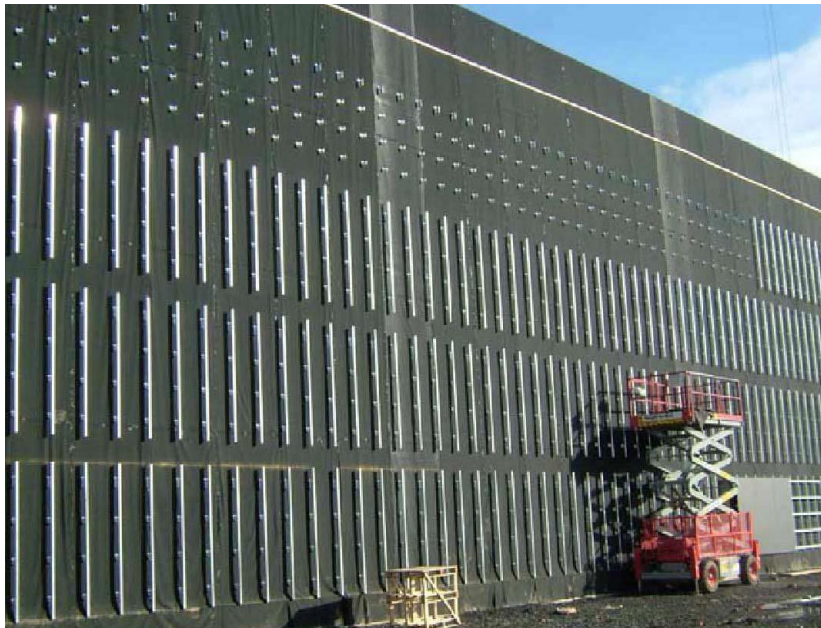


Fig. 6. EPDM Typical Application

14). Cavity Fire Stops.

The cavity design needs to incorporate cavity barriers to prevent the spread of fire both vertically and horizontally. The primary function of the system is to maintain continuity of fire resistance (smoke) by sealing the gap between the compartment external curtain walls.

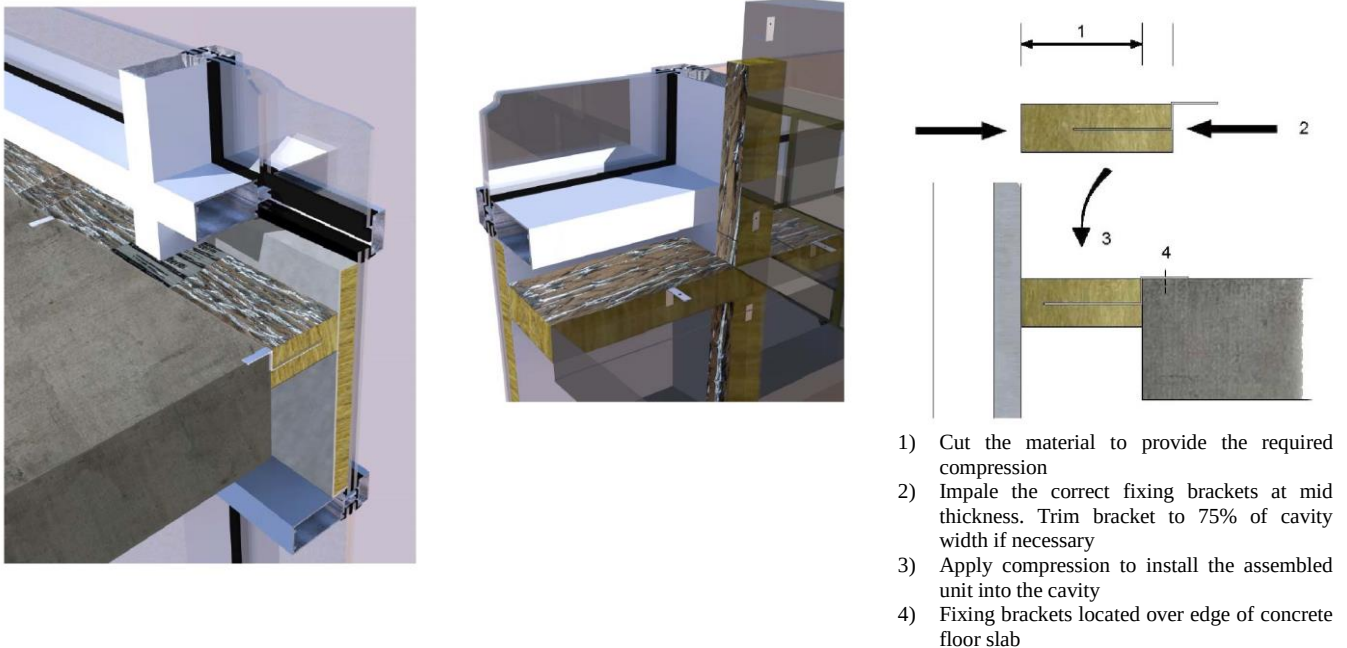


Fig. 7. Horizontal & Vertical Fires Stop Barriers – typical details.

15). Insulation.

Thermal insulation is a general term used to described products that reduce heat loss or heat gain by providing a barrier between areas that significantly different in temperature.

The most common types of insulation are made primarily from glass or rock that has been melted down at temperatures well in excess of 1000 °C and then, spun into fine strands of wool. The strands can then be formed into various products depending on where it will be used in a building – eg. solid slabs to install in cavity walls.

The insulation needs to be non-combustible, rot and vermin proof and non-absorbent. The insulation may have a foil layer to act a vapour control layer or a breather membrane applied to the outer face to control condensation.

In the design and selection stage important factor that need to be pay a special attention is “**U-Value**”.

U-Value is the measure of the rate of heat loss through a material. Thus in all aspects of building design one should strive for the lowest U-Values possible because the lower the U-Value – the less heat that is needlessly escaping. The calculation of U-Values can be rather complex – it is measured as the amount of heat lost throught a one square meter of the material for every degree difference in temperature either side of the material. It is indicated in units of Watts per Meter Squared per Degree Kelvin or **W/m²K**.

Structure element : Wall
Description : External wall insulation (fixed with fasteners of lambda value or part of it less than 1 W/mK)
Calculated 'U' value = 0.15W/m²K (Calculated in accordance with BS EN ISO 6946)

(Correction for mechanical fasteners, $\Delta U_f = 0.0116 \text{ W/m}^2\text{K}$ | Correction for air gaps, $\Delta U_g = 0.0000 \text{ W/m}^2\text{K}$)
(Alpha 0.8 m^{-1} | Fasteners per square metre 2.2727)
(Fasteners cross-sectional area 28.260 mm^2 | Thermal conductivity of fastener 50.00 W/mK)
Correction for rain screen cladding, $\Delta U_{rc} = 0.0405 \text{ W/m}^2\text{K}$
(x : 0.180 n : 0.225 per m^2)

Element Description	Element Thickness (mm)	Thermal Conductivity (W/mK)	Thermal Resistance ($\text{m}^2\text{K/W}$)
Outside surface resistance	-	-	0.040
SANDSTONE	40.0	2.300	0.017
UNV. A/SPACE;	40.0	-	0.644
KOOLTHERM K8	180.0	0.020	9.000
CONCRETE 1:2:4 2000 kg/m^3	200.0	1.400	0.143
Inside surface resistance	-	-	0.130

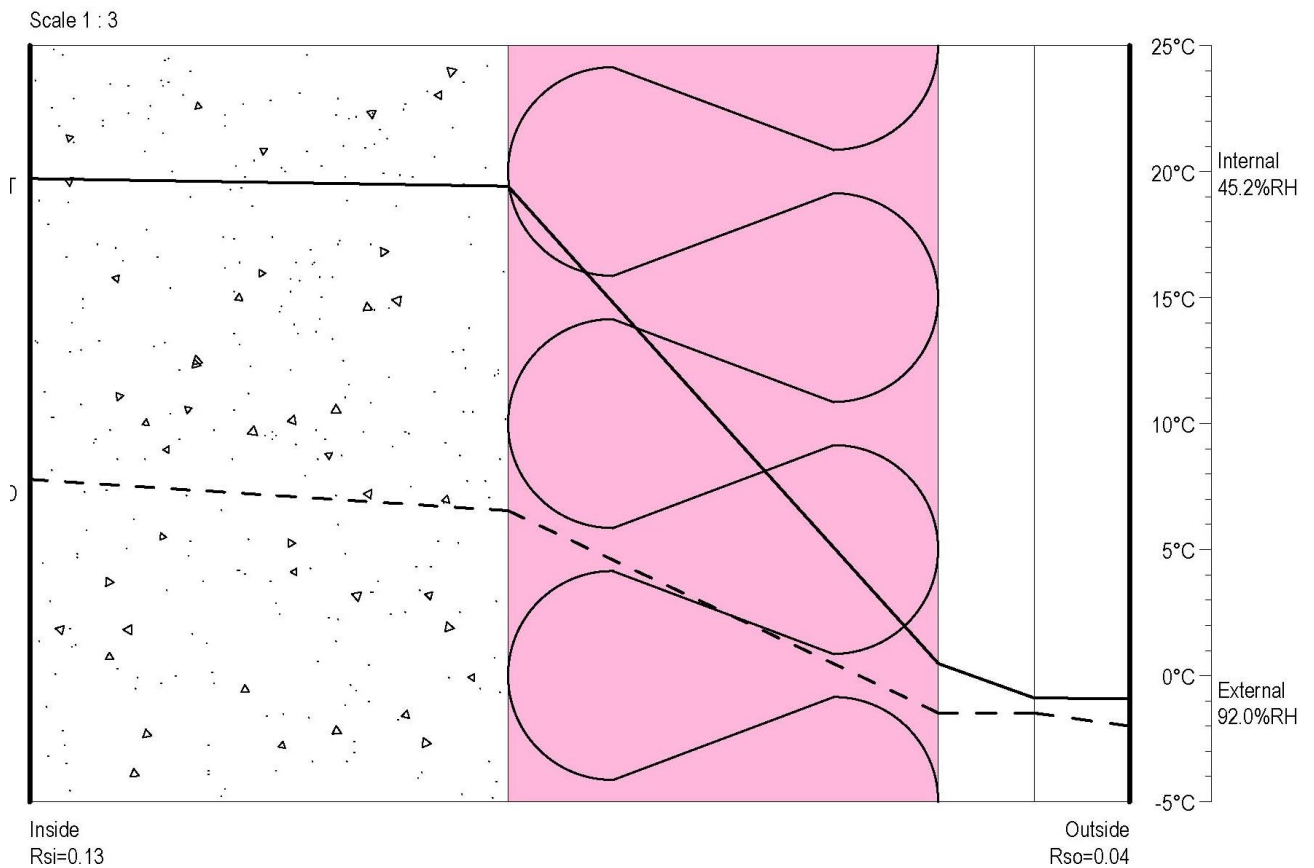


Fig. 8. U-Value Calculation sheet – typical detail.

Structure element : Wall
Description : External wall insulation (fixed with fasteners of lambda value or part of it less than 1 W/mK)
Calculated 'U' value = 0.20W/m²K (Calculated in accordance with BS EN ISO 6946)

(Correction for mechanical fasteners, Delta Uf = 0.0158W/m²K | Correction for air gaps, Delta Ug = 0.0000W/m²K)
(Alpha 0.8 m⁻¹ | Fasteners per square metre 2.2727)
(Fasteners cross-sectional area 28.260 mm² | Thermal conductivity of fastener 50.00 W/mK)
Correction for rain screen cladding, Delta Urc = 0.0405W/m²K
(x : 0.180 n : 0.225 per m²)

Element Description	Element Thickness (mm)	Thermal Conductivity (W/mK)	Thermal Resistance (m²K/W)
Outside surface resistance	-	-	0.040
SANDSTONE	40.0	2.300	0.017
UNV. A/SPACE;	40.0	-	0.644
KOOLTHERM K8	120.0	0.020	6.000
CONCRETE 1:2:4 2000 kg/m³	200.0	1.400	0.143
Inside surface resistance	-	-	0.130

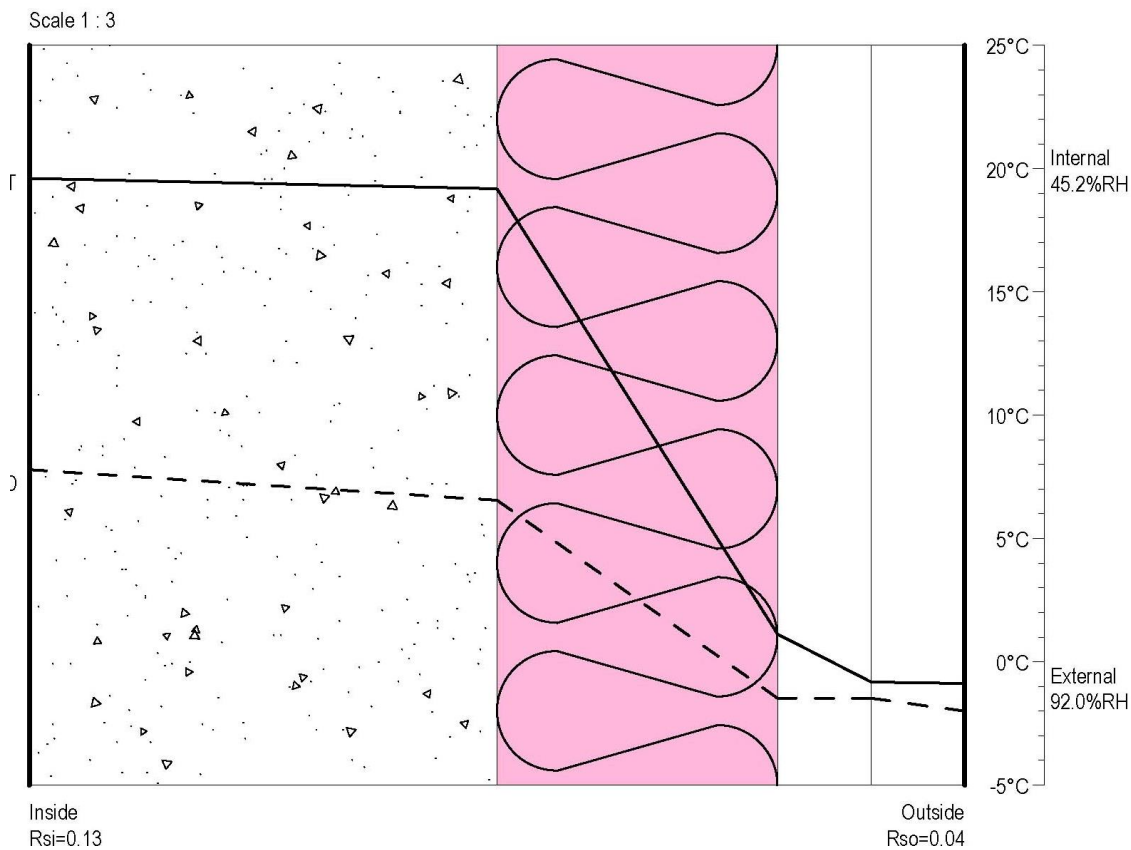


Fig. 9. U-Value Calculation sheet – typical detail.

Note: These U-Value is provided as a guide only. U-Value may vary depending on the particular construction.

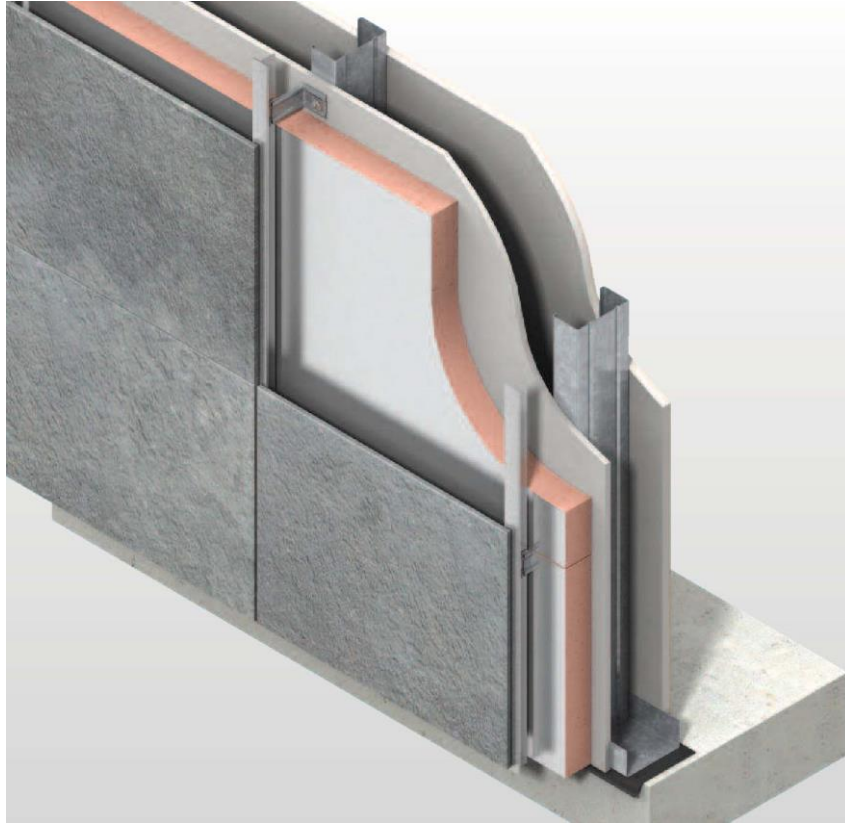


Fig 10. Insulated Cladding Wall – Typical Detail.

Stone Paving

Natural Stone.

The major benefits of the natural stone paving/floor tiles are its strength, durability and aesthetic appeal. Natural stone paving is stronger than concrete, but it can withstand large amounts of traffic as well as constant and extreme temperature changes. Another major advantages of the natural stone paving is water resistant and it is hundred percent environmentally friendly.

Natural stones suitable for paving/flooring use and their surface finishes:

- Granite – Can be used internally (polished, eggshell, honed and fine rubbed) and externally (bush hammered, flame texture, air abrasive blasted or tooled).
- Limestone – Can be used internally (fine rubbed, honed and sawn finish) and externally (bush hammered, sand blasted or tooled).
- Marble, Travertine – Used mainly internally (polished, honed or gritted).
- Slate - Can be used internally (fine rubbed and sawn finish) and externally (riven or flame textured).
- Sandstone - Can be used internally (fine rubbed and sawn finish) and externally (riven or flame textured).

The designer should satisfy himself that the flooring/paving proposed is suitable for the conditions contemplated. There are a number of factors that need to be considered by the designer: appearance, intended use, colour, paver size and thickness, but the most importantly the substrate that will provide the strength.

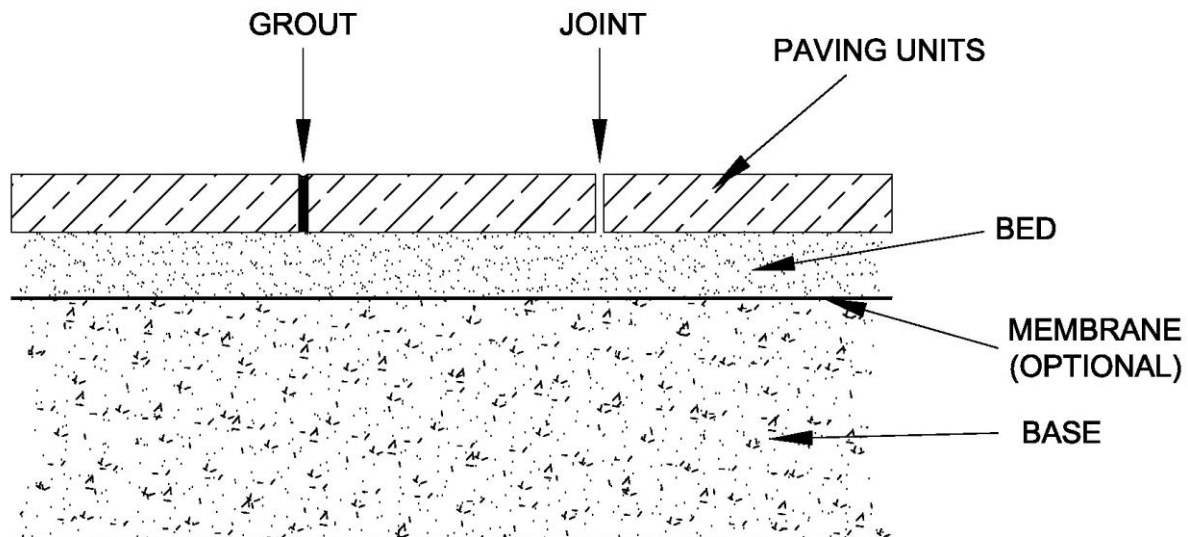


Fig 1. Paving Section – Typical Detail

Structural Base.

It is essential that the base provides solid foundation for the paving. Where movement is a possibility it may be wise to use reinforced strong concrete base. Sand screed and aggregate bedding are the most common bases for the stone paving. Often used as an intermediate layer between the structural base and bed to provide a true and even surface on which to apply finish. The base should be laid to an accurate level $\pm 15\text{mm}$ to ensure that the bedding is kept in appropriate range – see table 1.

Membrane.

Isolation of the flooring bed from the base (Optional). Depending on the site it may be worth considering a waterproof membrane between the concrete base and the bedding to impede the possibility of staining water seeping through the base to the stone. Also failure arising from variable stresses can be avoided by isolating the flooring bed from the base by a separating layer that prevents the two elements from adhering to each other and thus allow each to move independently. Another method of isolating base and flooring bed is to use a semi-dry cement : sand bed. The dryness of the mix results in every weak adhesion between the bed and the base and any cleavage can occur at the interface in the event of differential movement.

Bed.

All natural stone units should be solidly bedded generally on a sand and cement semi-dry mix. Alternatively the paving can be solidly bedded on a sand and cement mortar bed. For light colored granites, limestone and marbles it is imperative that only clear sands and white cement are used in the bedding to avoid the possibility of staining being drawn into the stone. Stone flooring units may also bedded in adhesive.

FLOORING BEDS: Final thickness and suitability						
Type of bed	Thickness Min mm Max mm		Terrazzo tiles & slabs	Limestones & Sandstones	Marbles, Granites, Slates and other	Composition block
Cement: sand mortar	15	25	S	C	S	S
Flooring units less than 10mm thick	10	15	n/a	U	C	n/a
Flooring units of variable thickness	20	30	n/a	C	S	n/a
Cement: sand semi-dry mix	25	70	S	S	S	U
Cement: sand semi-dry mix over a separating layer	40	70	S	S	S	U
Cement: Lime: Sand mortar	15	25**	U	S	U	U
Adhesive	1	6*	C	C	C	S
* Some may be applied up to 12mm thick for filling small isolated depressions. ** May be applied up to 50mm thick for large flooring units.						
KEY S – Suitable C – Confirmation suitability with the manufacturer or supplier U – Unsuitable n/a – Not applicable						

Table 1. Flooring Beds – BS 5385

Grout materials.

Grout materials should have good working characteristics, low shrinkage and good adhesion to the side of the joints. Additional properties may assume special importance: impermeability, resistance to water, heat, cleaning agents and chemical attack, resistance to mould growth and bacteria, resilience and compressibility.

Stresses may result from factors such as drying shrinkage, deflection and moisture movements in the base and thermal and moisture changes affecting the flooring/paving. These stresses can sometimes cause loss of adhesion and bulging or cracking of the flooring and to counteract this movement joints extending through the flooring and its bed should be incorporated in the installation.

The designer should assess the magnitude of any stresses and decide where movement joints, flexible joints and contraction joints should be located, having regard to all the relevant factors including the type of flooring and bed.

The three types of movement joints are as follows:

- a). Flexible joints aligned to structural movement joints,
- b). Flexible movement joints to accommodate smaller movements than structural joints
- c). Contraction joints which are non-compressible to relieve tension.

Joint materials and its flexibility:

- Portland cement mortar – rigid
- High alumina cement mortar – rigid
- Rubber latex cement – slightly resilient
- Furane resin – rigid and tough
- Epoxide resin – rigid and tough.

In general grouting can be carried out at any time to suit the convenience of the work but preferably should be left for at least 12 hours after the completion of laying of the floor/paving units. It is essential to allow sufficient time to elapse to ensure adequate setting of the bed to preclude disturbance of the flooring units during the joint finishing operation. However, it is advisable not to delay the grouting/pointing unduly, as open joints may collect general dust and deleterious substances.

Granite, marble and slate with smooth finishes.

The most satisfactory results are obtained when these materials are laid with narrow joints. These however, should be of sufficient width to permit adequate penetration of the grout. The joints should be completely filled with neat cement or modified cement grout worked into joints.

Granite, slate and quartzite with textured and riven finishes.

Generally, the minimum joint width is 6mm in order to take up any slight variations in the slab surface thereby avoiding projecting edges. For textured or riven surfaces, it is sometimes desirable to use a dry brush to remove surplus material before wiping with a damp sponge or cloth.

When the bed has stiffened the joints should be pointed with mortar consisting of 1 part cement to 3 parts fine sand. Once the mortar has sufficiently set the face should be thoroughly cleaned.

Care should be taken to ensure that surplus mortar is not allowed to harden on the floor surface.

The paving needs to be laid to fall, typically 1 : 50 to ensure that water runs off and puddling does not occur, which can cause slipping hazards in freezing weather, as well as concentration of damaging salts as the puddle evaporates. Consideration should also be given in the design to potential run offs onto the paving. These run offs can wash nutrients and debris that can encourage the growth of algae or potentially damaging de-icing salts from surrounding roadways.