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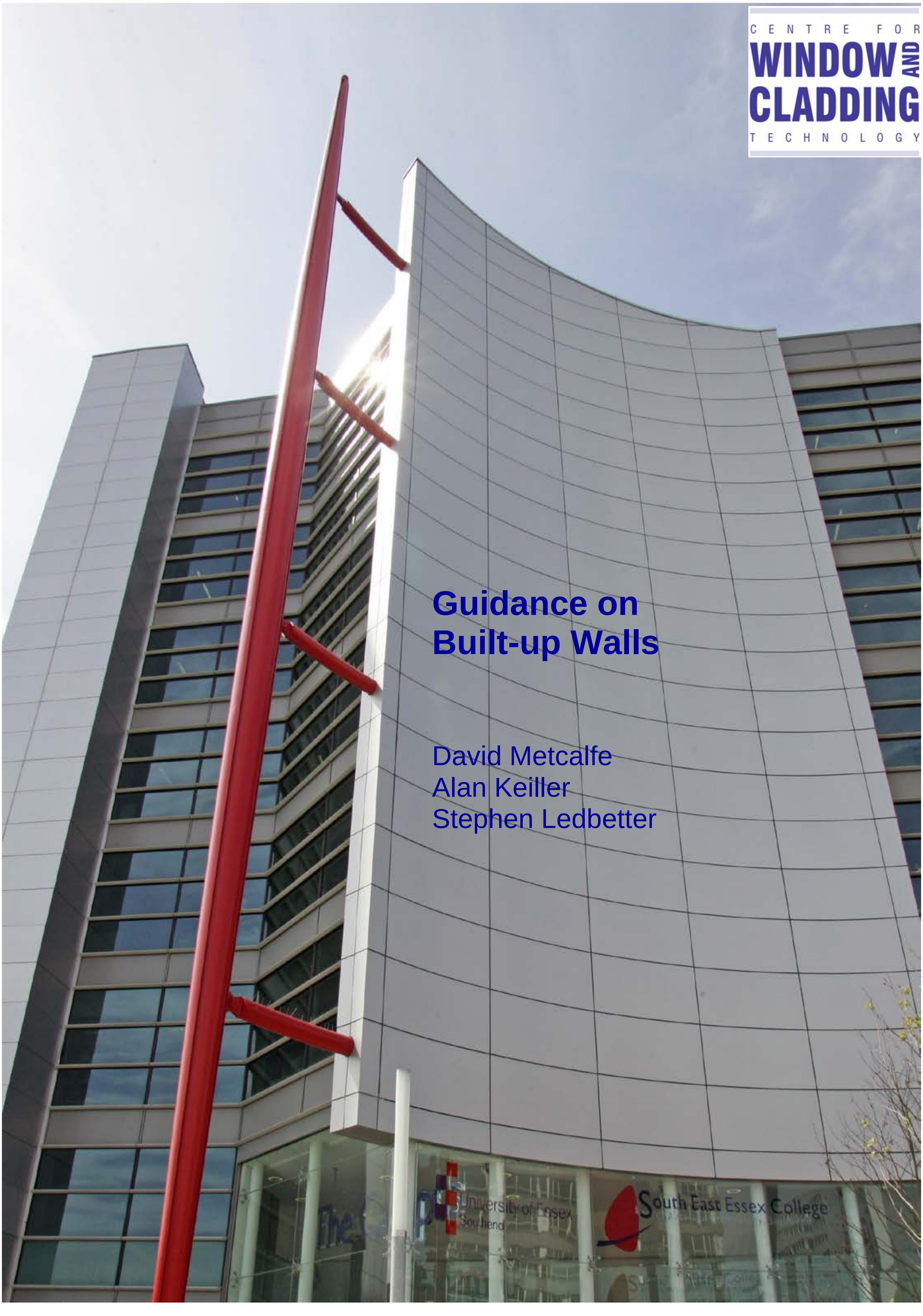

Guidance on Built-up Walls

David Metcalfe
Alan Keiller
Stephen Ledbetter

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This document was written by the CWCT Built-up Walls Group, comprising:

David Alexander-White, National House-Building Council
Peter Barr, SIPCO
Neil Brownlie, STO Limited
Steve Bryceson, Marley Eternit Limited
David Cottrell, Independent Consultant
Aubrey Edgley, Kingspan Limited
Graham Fairley, Society of Façade Engineering
Andy Ffolkes, Ffacesolutions
Dr Richard Harris, Sandberg
Mark Heywood, Mark Heywood Associates
Nick Jenkins, Booth Muirie
Alan Keiller, CWCT
Shaun Kelly, Cladtech
Dr Stephen Ledbetter, CWCT
John Libby, Laing O'Rourke
William McDowell, Rockwool Rockpanel
Eilis McShane, Multiplex Construction Europe
David Metcalfe, CWCT
Steve Wild, Tremco illbruck
Dr Bill Wolmuth Independent Building Technology Ltd

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FOREWORD

Built-up walls are essentially layered construction, often formed from components and materials from a number of different suppliers and manufacturers, installed in a series of independent operations by different contractors. This differs from traditional cavity wall construction whereby the two skins of brickwork would be constructed by a single contractor, at the same time.

The principal layers that make up a built-up wall are:

- back wall;
- waterproof layer:
- thermal insulation;
- cavity (drained to the outside);
- outer finish (e.g. rainscreen, render)

Any number of these layers may be included in the wall build up, with the built-up wall defined as everything from the inside to the outside.

Although being used for around 100 years or so, built-up or layered walls have only become commonplace in UK construction over the past 30 years driven by a number of factors such as the requirement for increased levels of insulation; the desire for lightweight and economic forms of construction; and the availability of new materials. When designed, coordinated and constructed correctly they can offer a number of advantages over traditional forms of construction, however if detailed incorrectly serious issues may occur leading to degradation of materials and premature failure of the wall. Built-up wall systems utilising rainscreens and rendered wall systems (i.e. EWIS - external wall insulation systems) tend to be more complicated to design, procure and construct than other forms of layered construction and are the main focus of this document.

This guidance document gives advice on the specification, design, procurement, construction, use and maintenance of these forms of built-up wall system together with their materials and components. It is intended for use by all those involved in the above processes from client, building design team, building envelope designers, principal contractors, specialist building envelope contractors through to end users.

A built-up wall is excellent for covering large areas of flat uniform façade however its overall performance will often be limited to the various interfaces within and adjacent to it. Interfaces will disrupt the otherwise continuous air barrier and waterproof layer of a built-up wall. Unintended water ingress and air infiltration will result if measures are not taken to ensure integrity of these layers. In addition, thermal bridging at interfaces should be minimised to avoid unnecessary heat loss and reduce the risk of condensation forming. Interfaces can include abutments with other building elements (e.g. roofs, floors, other wall types), penetrations through the built-up wall (e.g. windows, service penetrations) and the various layers within the built-up wall itself.

Heavy emphasis is placed within the guidance document on the importance that the correct design and construction of these interfaces have especially with regards to where the responsibility for the interface lies. Examples of interface details are used throughout the document to illustrate the use and positioning of various materials and components in order to maintain the functional performance requirements of the built-up wall.

Advice is given on the functional performance requirements of built-up wall systems taking into account what regulations and standards apply, how to specify them and how they can be tested and assessed. The system performance requirements included in the document are:

- watertightness;
- airtightness;
- structural performance;
- robustness;
- movement;

- fire;
- thermal performance;
- condensation; and
- acoustics.

Durability is discussed from the onset of determining the design and service life of a built-up wall system through the selection of its primary and secondary components to its maintenance. The importance of having an appropriate maintenance strategy in place is a key aspect that can heavily influence the durability of a built-up wall system and should take into account the required frequency and method of cleaning and maintenance, means of repair and especially how access can be provided so work can be carried out in a safe manner.

The guidance document concludes with a summary in the form of checklists for built-up wall systems in both rainscreen and EWIS configurations. The checklists take a number of key aspects relating to the built-up wall which have been discussed throughout the document and look at some of the items which should be considered or taken into account in a built-up wall's specification, design and construction. The checklists also act as user-friendly guides through the document itself referencing relevant chapters and sections.

This document has been a long time in development and provides an extensive guide to a complex subject. We welcome comments you may have on the document, including any omissions that may be incorporated into future updates. In particular, we ask for good interface details that may be included in the Appendix.

1 INTRODUCTION

Built-up walls are essentially layered construction often formed from components and materials from a number of different suppliers and manufacturers installed in a series of independent operations. For example, with a rainscreen wall 'Contractor A' may be responsible for the back wall, 'Contractor B' responsible for windows/doors and 'Contractor C' responsible for rails and panels. This differs from traditional cavity wall construction whereby the two skins of brickwork would be constructed by a single contractor, at the same time.

The use of built-up walls has become commonplace in UK construction over the past 30 years. Their development has been due to a number of factors including:

- the desire/requirement to use increased thicknesses of insulation;
- the desire for light weight and economical forms of construction;
- the availability of new materials.

When designed, coordinated and constructed appropriately such wall systems may offer a number of advantages over traditional construction, however if detailed incorrectly serious issues of water penetration and trapped condensation may occur, particularly at interfaces, leading to degradation of materials and premature failure of the wall.

1.1 Scope of this document

Built-up walls used in modern construction may be categorised by the back wall construction or by the outer finish. These will include:

outer finish:

- rainscreen;
- render on insulation;
- brick slip;
- brick.

back wall:

- masonry;
- studs;
- concrete;
- composite insulation panels.

This document will concentrate on rainscreens and rendered wall systems since these are more complicated to design, procure and construct. They also tend to be used on a larger scale than masonry walls and therefore the consequences of failure are far greater. Traditional cavity walls are very well established and are only included in this introductory chapter for completeness.

1.2 Built-up walls

The principal layers/features that may make up a built-up wall are:

- back wall;
- waterproof layer:
  - o separate sheet/membrane,
  - o outer face of back wall,
  - o breather membrane;
- thermal insulation;
- cavity (drained to the outside);
- outer finish;
- features:
  - o interfaces,
  - o penetrations,
  - o openings,
  - o Attachments.

Any number of these features may be included in the wall build up, with the wall defined as everything from the inside to the outside.

The back wall may transfer load to the primary structure, or may be a loadbearing wall. It also generally provides the air barrier and any fire resistance of the wall, and may include additional layers such as a vapour control layer. **The control of moisture movement through the wall is vital to its long-term success.**

The back wall is also critical to the performance of rainscreen systems. The back wall forms the main air barrier in the overall construction. This may be:

- the wall itself;
- a membrane/continuous sheet attached to it;
- an internal dry lining system/plastered surface.

If air movements through the back wall are too high this will increase energy losses through the wall, which must meet regulatory requirements.

Back walls may broadly be categorised as:

- framed walls;
- solid walls.

The back wall is discussed in greater detail in Chapters 3 and 4.

Thermal insulation not only influences the U-value of the wall but its position also affects the risk of thermal bridging occurring (*Figure 1.1*) with the potential of condensation forming. These issues are discussed further in Sections 6.7 and 6.8.

Figure 1.1 - Dust staining on the internal surface at stud locations due to thermal bridging

A number of approaches can be taken to make a built-up wall watertight.

A cavity effectively drained to the outside will provide a means of removing any water that gets past the outer face of the wall (the first line of defence against water penetration) and add to the overall robustness of the wall. In a drained and ventilated system air flow within the cavity will help to dry out any moisture present.

A drained cavity is an integral part of a rainscreen wall as due to the nature of the joints between the external panels, some water may enter the cavity and need to be removed, *Figure 1.2*. Other built-up wall systems rely on the ‘face sealed principle’ whereby the external surface provides a single line of defence against water penetration. If water gets past this outer seal there is no mechanism to remove it from the wall. Depending on the exact construction of the wall, insurers such as the NHBC may require a cavity in order for it to meet their specification, even if the outer surface is sealed. Cavity recommendations are discussed in Chapter 3.

The outer finish provides the required aesthetic effect and also acts as the first line of defence against water penetration.

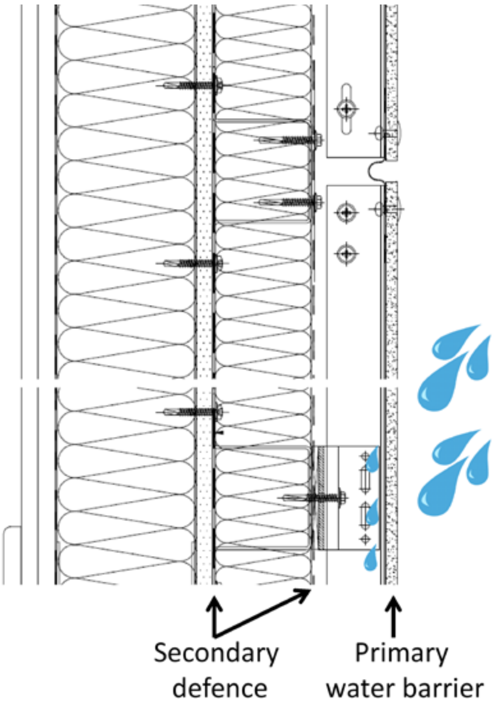

Figure 1.2– Rainscreen wall with drained cavity (secondary defence principle)

Windows will normally be included in a built-up wall, *Figure 1.3*. How the interface details (flashings, membranes, seals etc.) between the wall and window are designed and installed is crucial in ensuring that the performance of the wall, principally the water resistance, air tightness and the thermal performance, is not impaired.


Figure 1.3 - Different components of a built-up wall (rainscreen (left), external insulation (right))

1.2.1 Rainscreen walls

The principal features of a rainscreen wall are:

- outer skin of panels (i.e. the rainscreen);
- air cavity;
- backing wall.

As its name suggests, the purpose of the outer rainscreen panels is to shield the wall from direct rain. Typical panel materials include metals (such as aluminium, steel or zinc), stone (natural or composite), ceramics (such as terracotta), glass, fibre cement board, timber, GRP, phenolics and composite materials. Examples of rainscreen walls are shown in *Figure 1.4*.

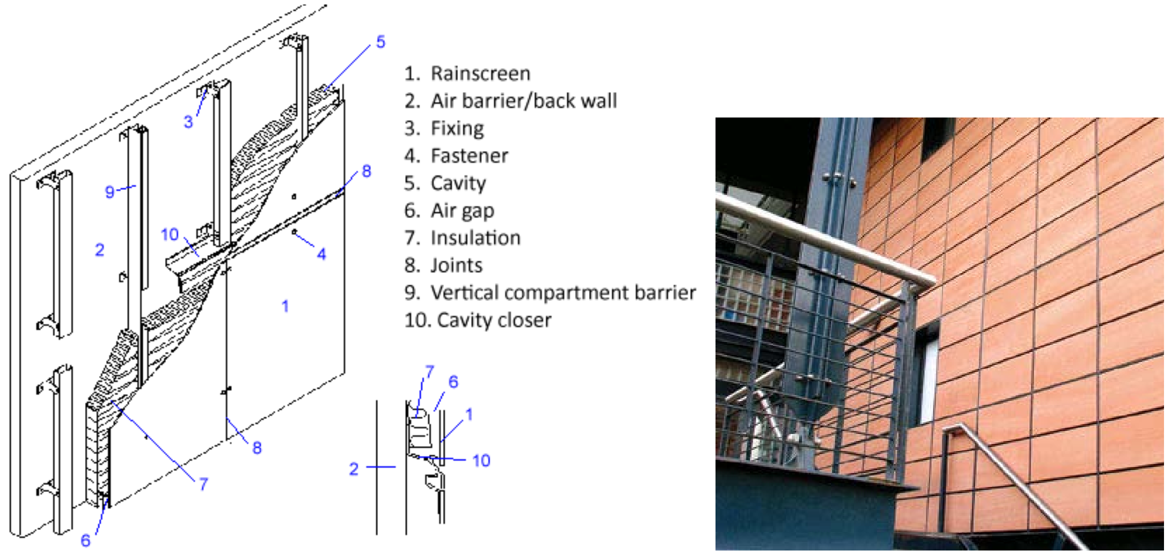

Figure 1.4 - Rainscreen walls

Traditional forms of rainscreen wall are tiles or slates hung on a wall, timber shingles and lap boarding. Modern rainscreens generally comprise panels larger than traditional tiles. The size is dictated by the architectural intent and the material used for the panel, with more brittle materials such as terracotta being smaller than metal or composite panels.

The joints between the panels may allow some water to penetrate. The degree of this penetration will depend upon the joint design between panels, amongst other factors. Joints may range from open joints, for example when using natural stone as the rainscreen, to labyrinth joints between some metal cassette panels. This is discussed further in Chapter 3.

The cavity between the panels and the backing wall is the primary feature of a rainscreen wall. Combined with the outer panels and the back wall it is designed to control/limit the passage of water into the wall. There are two main ways in which the air gap may be treated.

Firstly, the gap may be left continuous (it may extend over several stories and bay widths). With this approach water entering the cavity is allowed to drain downwards and outwards, and air movement is encouraged to dry out any water which remains. **The term 'drained-and-ventilated' is applied to this technique.**

The second method is to compartmentalise the cavity. At least one joint at the perimeter of the panel is left unsealed or open, to enable pressurisation of the air gap, which then limits water penetration by virtue of the reduced pressure difference across the panel. **The term 'pressure-equalised' may be applied to this technique.**

Other components that may make up the rainscreen system include support rails for the outer panels, insulation, breather membranes, vapour control layers, sheathing boards and fixings. These components and materials are discussed in more detail in Chapter 4.

Interfaces within rainscreen systems, such as those around a window or door, and interface with other elements of the building, such as the roof, floor slabs and adjacent cladding systems are also vital to the overall performance and will be discussed in Chapter 5.

1.2.2 Rendered walls

Renders of one form or another have been used on buildings for many hundreds of years. Until the invention of Portland cement in the nineteenth century lime based renders were commonly used. These renders consist of a binder (lime), an aggregate (sand, crushed stone etc.) and water, and are often called stucco (especially in North America).

Lime is porous - It allows the building to 'breathe' by absorbing water from the structure which then evaporates. This keeps the structure dryer and lessens the risk of spalling. Lime based renders are also reasonably flexible so they move with the structure which helps prevent cracking. For these reasons lime based renders are still used in the repair and restoration of older buildings which have solid walls. For these applications it is also important that the render is weaker than the substrate onto which it is being applied, so that if there are any large movements, or if there is water penetration, the render fails rather than damaging the underlying surface.

Cement is now used extensively in conventional renders due to its ease of use, quick setting and compressive strength, however lime is still often added to increase the permeability and workability of the render. Varying the proportions of cement, lime and aggregate will produce renders with different properties, ranging from very strong and impermeable (1:1/4:3, cement:lime:sand ratio) to weaker, more flexible and more permeable (1:2:9).

Examples of rendered walls are shown in *Figure 1.5*.

Figure 1.5 - 'Stucco' render (left), lime based render (right)

The forms of construction described above are well established. This document will concentrate on 'modern' external render systems. Such systems will be insulated and may include a cavity within the wall build-up.

There are several names used that describe these systems:

- **ETICS** – Exterior Thermal Insulation Composite Systems. This is the terminology that is widely used in Europe and in the European Technical Approval Guide, ETAG 004 – *Guideline for European Technical Approval of external thermal insulation composite systems with rendering*;

- **EWIS** – Exterior Wall Insulation Systems. This terminology is used by the British Board of Agrément (BBA) and is widely understood in the UK;

- **EIFS** – Exterior Insulated Finish Systems. The terminology is used in the USA and Canada and is used by some suppliers and contractors working in the UK.

EWIS will be used in this document when describing externally insulated render wall systems.

Depending on the material used and the substrate onto which it is applied, the render may have to be applied in several layers and reinforcing coats and meshes may be used in the build-up of the wall. Reinforcements may also be required at junctions and penetrations, such as around window openings, in order to control cracking of the render due to differential movements.

Render materials used for external insulation are generally proprietary materials which may be:

- cement based;
- polymer modified cementitious materials;
- polymer based materials.

Polymer and polymer modified cementitious renders are used in thicknesses from a few millimetres up to 15 mm, whereas conventional cementitious renders are used with a metal lathing in thicknesses of 25 mm or more.

The substrate to which the EWIS is attached may be a solid masonry construction, or it may be a framed wall with sheathing/carrier boards attached to provide a level surface. Solid back walls will generally have less movement and therefore the render is less prone to cracking, however when a cavity is incorporated behind the insulation greater movement can be expected. With framed back walls movement may be greater and this must be taken into account during the design of the render system. Retention of the insulation may depend solely on adhesives or mechanical fixings may be used.

An established use for EWIS is for refurbishment of existing buildings. This may:

- improve thermal insulation;
- reduce condensation on internal surfaces;
- stabilise deteriorating surfaces;
- improve appearance.

In many cases these walls will be masonry construction. The type of EWIS applied will depend on the condition of the existing wall; if the existing surface is sound the insulation may be applied directly to the wall, whereas if the surface is in poor condition sheathing or a wire mesh lath may need to be applied to provide a suitable surface to build upon. These requirements are discussed in further detail in Chapter 3.

A variety of different finishes is possible with EWIS. The texture of the render finish will depend mainly on the grain size used in the render and tools used for the final application. Alternatively brick slips may be applied to form the outer layer of the wall.

Examples of insulated render systems are shown in *Figure 1.6*.

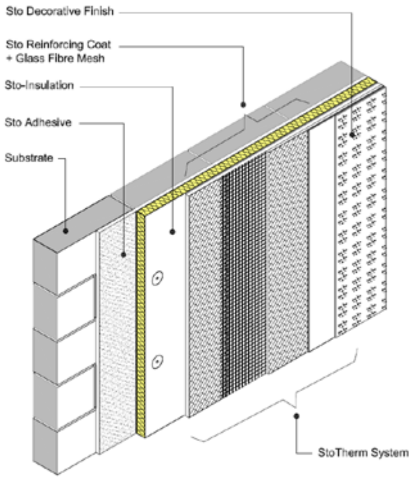

Figure 1.6 - Example of insulated render systems (© Sto Ltd.)

1.2.3 Brick slip walls

Brick slips are a lightweight, thin facing applied to a built-up wall to give the impression of traditional brick wall finish. Construction is generally more straightforward than traditional brickwork meaning potentially shorter construction times

The brick slips themselves may be thin clay bricks (typically 20mm), or a synthetic alternative (approximately 5mm). Brick slips may be used over an entire façade, or limited to specific areas, such as slab edges where brickwork is being used as an infill to give a consistent appearance.

Brick slips may be used on new or existing facades.

The components required to construct a brick slip wall may include:

- backer panels;
- guide/fixing rails;
- meshes;
- fixings to the substrate;
- adhesive;
- brick slip;
- mortar.

The main issue associated with brick slips is that of water ingress. This can take a number of forms. Firstly, ingress may occur at penetrations and interfaces such as around window openings. Water ingress may also occur due to the brick slip system cracking. This may be the result of an impact or due to excessive movement of the back wall.

Water may also penetrate into the system as a result of the porous nature of brick. If the brick slips are subjected to prolonged wetting, then the water may soak through to the adhesive behind which may affect the bonding. This is more of an issue for brick slips than traditional brickwork due to reduced thickness of brick, especially where a drainage cavity is not incorporated.

Brick slip systems are briefly introduced below. The rest of this document focusses on rainscreen systems and EWIS, however the principles described throughout may also be applied to brick slip systems. These systems will be described in further detail when this document is revised.

1.2.3.1 Brick slip systems

The simplest form of brick slip is shown in *Figure 1.7* below.

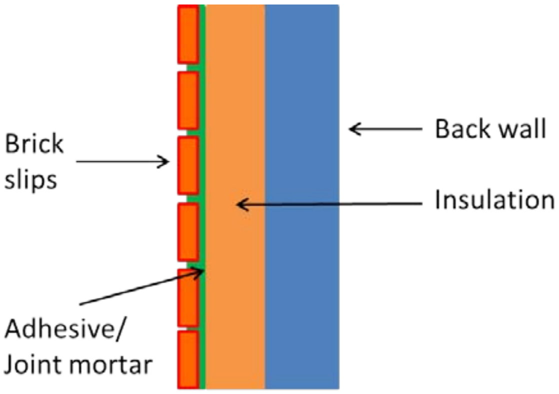

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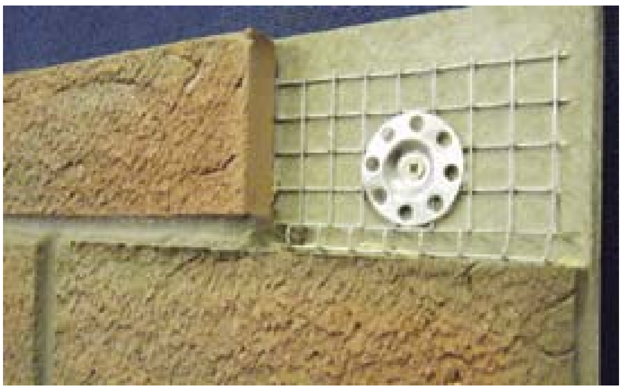
Figure 1.7 – Brick slip on external insulation

The exact details of the construction will depend on the individual system, however there are certain principles and features that are common. Firstly, a suitable surface is required onto which the brick slips are bonded. This may be the insulation itself, or take the form of separate backerboard, a backerboard pre-bonded to the insulation or a steel/stainless steel mesh fixed back to the substrate (*Figure 1.8*). In addition to providing a suitable surface this layer also acts as an installation guide. They are specially designed to aid in accuracy and alignment of the brick slips.

An adhesive is then applied to the substrate and the brick slips are fixed into place. Once dry, a cement-based mortar is used as pointing between the brick slips.



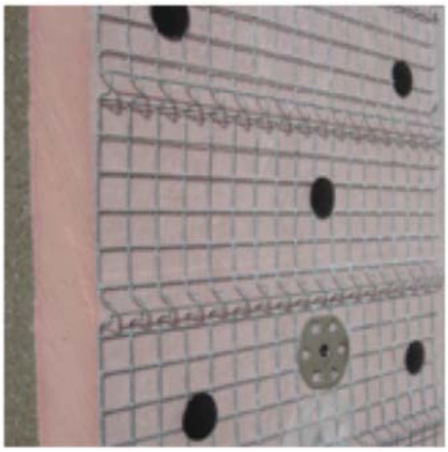


Figure 1.8 - Brick slip meshes

Specially shaped brick slips are available for corners, window reveals and other features such as arches.

The elements required to construct a brick slip wall may be procured as individual components, or alternatively a number of companies offer a complete system approach to the build-up.

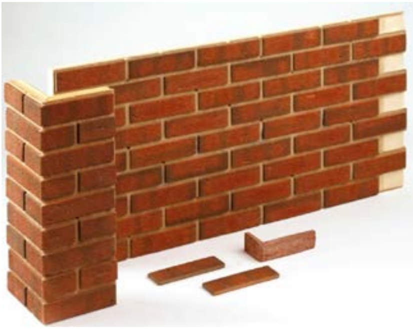
If separately procured components are used, it is vital they are compatible with each other and compatible with the substrate. A brick slip system may therefore offer a more reliable and robust solution; however, it must still be ensured that the system selected is suitable for its intended purpose.

Brick slip systems can be applied to most substrates; however, the back wall construction is an important consideration in the selection of the system used. Framed backing walls will have greater movement and deflection then solid masonry walls and it is vital that this is taken into account in the design of the brick slip system. This may require different sheathing boards and fixing arrangements for example.

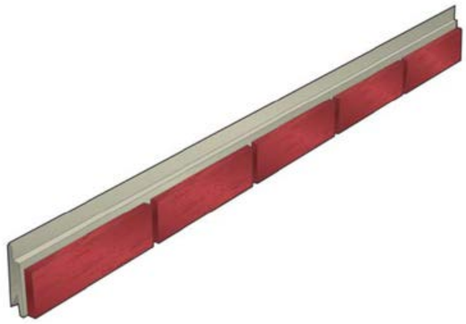
As well as traditional clay, synthetic (usually acrylic resin based) brick slips are available. These tend to be used as part of an EWIS in place of the normal render finish – an adhesive is applied to the reinforcing render coat and the brick slips are fixed directly. Acrylic brick slips are thinner than clay (approximately 5mm compared to 20mm) and therefore additional pointing is usually not required – the residual adhesive between bricks can be tooled to give a smooth appearance.

1.2.3.2 Brick slip panel systems

Various brick slip panel and rail systems are available. These are designed to offer a high level of prefabrication in order to speed up the installation process. Systems may be insulated or non-insulated.

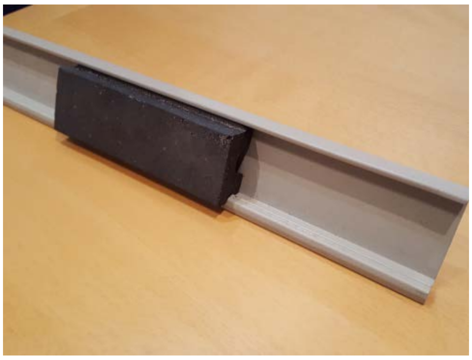


(a) Gebrik © Isosystems



(c) © Advanced Construction Systems

(b) © Stofix



(d) Corium system

Figure 1.9 - Brick slip panel systems

Typically the brick slips are attached to the rail/panel in the factory and then fixed back to the substrate, with the exact fixing arrangement dependant on the individual system. Joints between adjacent panels are pointed after installation. Panels may be square edged or interlocking. Some systems (*Figure 1.9* (d)) require the rails to be fixed to the back wall first, with special bricks which then clip into the rail, before all joints are pointed. Alternatively a 'unitised' approach may be taken whereby large panels are pre-fabricated before rapid assembly on-site.

Insulated systems (*Figure 1.9*(a)) are similar in nature to EWIS, with the slips bonded directly to the insulation. The complete panel is mechanically fixed to the back wall, typically using screws.

Non-insulated systems (*Figure 1.9* (b) and (c) in) that incorporate a cavity behind the panel/rail are similar in nature to rainscreen systems. The panel/rail material varies between systems. For example, *Figure 1.9* (b) and (d) use galvanised steel, (c) uses cement particleboard.

All systems can be constructed with a drained cavity, as recommended in Section 3 of this document. This may be achieved using proprietary rails and brackets (*Figure 1.9* (b)), or by using treated timber battens (*Figure 1.9* (a) and (c)).

1.3 Performance of built-up walls

There are a number of key performance criteria that all built-up walls must always meet. These include:

- water and weathertightness;
- airtightness;
- structural performance;
- impact resistance;
- movement accommodation:
  - of the main structure,
  - of the built-up wall;
- fire;
- thermal performance;
- condensation;
- acoustics.

How these performance requirements are achieved in practice will depend on the level of performance required and the exact nature and construction of the built-up wall.

Other aspects of the design that must be considered include:

- appearance;
- fit and tolerance;
- construction and buildability;
- maintenance;
- repair.

1.4 Responsibility for performance of built-up walls

Built-up walls are often constructed by multiple contractors, each responsible for one or more layers of the wall. The overall performance of the wall is dependent upon how the individual layers work together and therefore coordination between contractors and compatibility between components are key areas which must be suitably addressed.

It is important to recognise that changing one element/component of the wall could affect several aspects of performance. For example, the sheathing boards may affect the air permeability of the wall, the loads that can be carried, the deflections of the framing members/support rails, and the impact performance. Similarly, the choice of brackets will affect the loads that can be carried/transferred, the deflections of the external panels and the impact performance. In addition, they will have significant influence on the overall U-value of the wall and the condensation risk.

It is therefore essential that somebody has contractual responsibility for concluding the design of the built-up wall, including any interfaces, to ensure it performs as specified.

How the different elements of the wall influence the overall performance is summarised in *Table 1.1* and will be discussed in greater detail in later chapters.

	Water leakage	Air permeability	Condensation	U-values	Loads	Deflections	Impact	Fire
Rainscreen panels	✓				✓	✓	✓✓✓	✓
Panel joints	✓✓				✓✓	✓		✓
External render	✓✓✓		✓✓		✓✓	✓✓	✓✓✓	✓✓
Cavity barriers	✓✓✓			✓	✓			✓✓✓
Flashings	✓✓✓			✓✓				✓✓✓
Breather membrane	✓✓✓	✓	✓					
Insulation			✓✓	✓✓✓				✓✓✓
Vapour control layer	✓✓	✓✓	✓✓✓					
Brackets	✓		✓✓	✓✓	✓✓	✓	✓✓	
Fixings					✓✓✓	✓✓	✓✓	
Framing			✓	✓	✓✓	✓✓✓	✓✓	
Sheathing	✓	✓✓✓			✓✓✓	✓✓	✓	✓
Internal lining/air barrier		✓✓✓	✓✓					

Table 1.1 – How the individual elements of a built-up wall influence the overall performance

Built-up walls comprise a number of elements that are constructed/brought together on site. There may be a degree of offsite construction involved in the wall, however even in such cases there is still a significant reliance on onsite construction. Therefore, their performance is heavily dependent upon the quality of the installation. The design of the wall may be perfectly adequate, however if those details are not translated to the actual wall the performance will suffer as a result. General workmanship issues together with factors such as the ease of construction must be considered.

The specification, design and procurement are crucial to the success of a built-up wall and will be discussed in greater detail in Chapter 2.

1.5 Advantages of built-up wall and drivers for use

The architectural intent and budget of the project will be the major factors in deciding the type of cladding/wall system to be used. Built-up walls are particularly well suited where there are large, flat, opaque areas, *Figure 1.10*.

There is a wide range of cost, depending on the complexity of the project and the materials used.

Once the back wall has been completed and any windows fitted work can begin on the internal fit-out before the external works have been finished. This may allow for a quicker overall build time.

A wide range of external finish is possible using various size of panel made from metal, timber, ceramics and so on, to coloured renders of varying texture, to a more traditional appearance using brick slips.

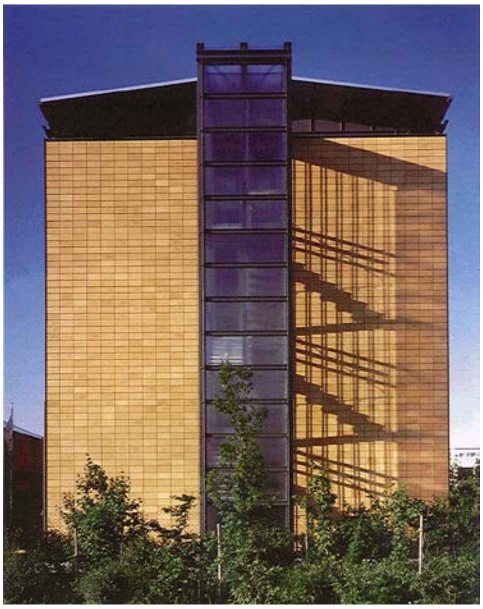


Figure 1.10 - Built-up walls – insulated render and rainscreen systems

Recent concerns regarding climate change and energy use in buildings have resulted in the tightening of many national regulations on thermal performance, meaning that an ever greater thickness of insulation is being required in new buildings. Built-up walls, either rainscreens or EWIS, are well suited for this as the insulation thickness can be easily varied to suit the project, without significantly changing the overall wall construction, however insulation levels have now reached the point where additional insulation may require a greater overall wall thickness.

It should be noted that simply improving the U-value of the built-up wall may not result in the lowest energy use for the building and may lead to overheating issues if measures to control this are not considered. A whole building approach is required in order to determine the best possible performance of the building, including factors such as:

- building use;
- location;
- construction type (thermally heavyweight or lightweight);
- orientation;
- ventilation/servicing strategy;
- façade configuration (U-values, glazed area, shading devices etc.).

Their lightweight and freedom of layout make rainscreens and EWIS suitable for refurbishing existing buildings (overcladding). Existing buildings account for a significant proportion of the carbon emissions from the UK building stock so their refurbishment is likely to be an area of significant market development in the coming years if the government's reduction targets are to be met.

Thermal bridging within built-up walls can be minimised, particularly with EWIS. Often support rails are completely embedded within the insulation layer and are therefore protected from the external environment. Alternatively, adhesives may be used to bond the insulation to the substrate. Rainscreens require brackets penetrating the insulation layer hence forming thermal bridges, however these can be reduced by suitable bracket design, and their effect taken into account in the thickness of insulation used.

In recent times some rainscreen systems have incorporated energy saving measures as pressures to reduce the energy use in buildings has increased. These have included using photovoltaic (PV) modules as the panels of the rainscreen, and using the cavity behind the panels to preheat the air before entry into the building. These are very specialist applications and will not be discussed further in this document.

1.6 Consequences of use

Due to the splitting up of the construction of layered walls into work packages, one of the major problems associated with built-up walls is that of coordinating the design and installation and assigning responsibilities for the different aspects of performance, such as the air tightness and water penetration resistance. There is often no single controlling mind or point of responsibility and therefore there is a significant risk that important details will be overlooked and the performance will suffer as a result.

The design is further complicated where there are windows and doors within the wall. Whilst the wall may be built of standard, often proprietary components, it is the interfaces which will determine the overall performance. These will generally be bespoke to the project and will require suitable design, coordination and installation if they are to be successful.

Some companies offer a 'complete solution' for a built-up wall that includes all parts of the wall, windows, window pods etc. This really is the ideal situation; having a single contractor responsible for all aspects of the wall will help ensure that it performs as intended, and therefore offers a more reliable system. Such systems may be more expensive and unless specified it is likely that the façade will be split into layered packages during the tender stage, however the consequences of splitting packages in this way are often not fully understood which may result in sub-standard walls being constructed.

In addition to the potential issues during design and construction, there may also be difficulties in establishing responsibilities for remedial work in the event of failures.

Due to the construction method external access to the building will be required. The degree of access will depend on the size of the building and the type of wall system used.

Built-up up walls are often chosen for reasons of economy and speed of construction, however issues of access are often not fully considered at the outset which may lead to delays and further costs later in the project, which may be significant.

Depending on the level of prefabrication craneage may also be necessary. This is more likely to be the case where the backing wall is framed as shown in *Figure 1.11.*

Figure 1.11 - External craneage

Whilst built-up walls can offer high levels of performance they are a non-traditional form of construction that has not been fully understood and premature failures have occurred as a result of failure to:

- **establish the necessary performance requirements of each layer and interface for the specific build-up concerned**
- **detail correctly;**
- **allocate responsibilities for design and construction;**
- **construct correctly;**

Note that premature failure has been more prevalent with EWIS than with ventilated rainscreens.

There have been a number of issues in recent years in Canada and New Zealand involving premature failures of EWIS construction. Issues have arisen in both low-rise and high-rise buildings.

A study carried out in 1996 by the Canadian Mortgage and Housing Corporation (CMHC) looked at low-rise multi-unit timber frame residential buildings, a building type which had experienced significant numbers of problems. The study compared buildings which have experienced considerable problems with 'control' buildings of the same type which were performing as intended. The problems have included water penetration, damage to cladding systems and rotting and decay of wood components.

Overall, the results of the study indicate that the primary source of moisture leading to the performance problems was water entering the building from the exterior, rather than interior sources or construction moisture. Internal sources of moisture may however give rise to both surface and interstitial condensation problems, which may in the long term give rise to damage of surfaces and materials within the wall build up. Areas which have high moisture content, such as kitchens and bathrooms, or where general ventilation levels are insufficient may be particularly vulnerable.

About 90 per cent of the problems were thought to be related to interface details between wall components or at penetrations. Water would enter the wall assembly at such details and stay there long enough to initiate rot of wood and corrosion of metal components.

The problems were thought to originate during design and construction activities (due to lack of coordination, no overall design responsibility and poor details on drawings) and not as a result of operations and maintenance or defects in the materials.

Following on from the study above, the CMHC and the Homeowner Protection Office carried out a study of high-rise envelope performance in British Columbia in 2001. In all thirty-five buildings were studied, with 151 wall and window assemblies and 131 assembly interfaces. Sixty performance problems were described. Eight different types of cladding were included in the study although the majority of the walls were clad either with stucco or EIFS. The buildings ranged in height from 5 storeys to 28 storeys.

The results of the study indicate that exterior moisture penetration at interfaces between assemblies and at details within assemblies is the dominant cause of moisture problems in high-rise buildings. It also found that windows were a focal point for moisture problems. None of the walls that incorporated drainage cavities were found to have experienced problems.

It was found that the great majority of the damage was corrosion of metal components of the assembly, and wetting, staining and mould growth on sheathing and insulation. In terms of metal components, it was clear that levels of corrosion resistance typically used for fasteners and support structures in these buildings was inadequate to cope with the environment they are exposed to once the walls were wet. Severe damage was found to occur to exterior gypsum sheathing whereas walls utilising glass fibre faced gypsum sheathing showed lower extent and severity of damage.

From both of these studies it can be broadly concluded that problems were caused by:

- inappropriate design features for the particular climate;
- inadequate design and understanding in terms of interfaces;
- quality of construction and overall performance;
- an over-reliance on face sealed systems.

These studies indicate the significance of suitable design, construction, and interfaces which will be described in greater detail in later chapters of this document. Examples from the studies are shown in *Figure 1.12*.

Figure 1.12– Failure due to poor interface detail (left), repairs in British Columbia (right)

2 SPECIFICATION, DESIGN AND PROCUREMENT PROCESS

Built-up walls comprise materials and components that may be grouped by the layers or zones of the wall in which they are used and there exists a possibility to set up a supply chain that separates the components. This practice has been shown to be a recurring cause of failure of built-up walls.

This chapter explains how the specification, design and selection of every element of the wall should be undertaken in the context of whole wall performance. The appropriate selection of every layer of the wall, every component, such as a window, and every interface will depend on the other materials and components. It follows that each will determine the performance of other materials and components and in turn many aspects of the whole wall performance.

2.1 Specification

A specification for a built-up wall is normally a performance based specification. This flows from Building Regulations and Building codes that are performance based requiring levels of thermal insulation, safe loads and so on.

The CWCT *Standard for systemised building envelopes* is a performance based standard that may be applied to built-up walls. The Standard also includes prescriptive requirements.

The project specification. This may be based upon an architectural practice's in-house documentation, or on documentation supplied by a specialist specifying service. The most widely used example of the latter is the National Building Specification (NBS). NBS Specification Section H92 covers rainscreen cladding and M21 covers external insulated render systems.

The NBS specifications are part performance based and partly prescriptive.

Whoever is responsible on the project contractually for determining the build-up of the walling should review the specified requirements for each layer of the project specific build-up, so that the overall specified performance of the façade is achieved even if the various layers are detailed and installed by different subcontractors.

National House Building Council (NHBC) technical standard Chapter 6.9 covers rainscreen cladding and insulated render systems. The NHBC standards are part performance based and partly prescriptive.

Within a performance specification there may be prescriptive clauses relating to materials, finishes and so on establishing a minimum standard for those features that affect appearance and durability.

A performance specification places responsibility for design on the Main Contractor and, if passed on contractually on the specialist façade contractors. It is important to understand the implications of devolving design responsibility to a specialist contractor. A contractor can only produce a successful design that delivers the required whole wall performance if they are either:

- responsible for the design of all components of the wall that affect the required performance;

  or

- fully informed of, and preferably involved in, all design decisions by other contractors that may affect the whole wall performance.

The first approach is to be preferred as there is a single responsible body and less risk of information not being communicated correctly.

There are two primary approaches open to the Architect/Main Contractor; they can either:

- use a largely performance based specification that requires the specialist contractor to undertake the detailed design of the complete wall;

or

- undertake a sufficiently detailed design of the wall to enable them to specify the various layers and components separately. It follows that they must also detail the interfaces.

In practice there is a lack of clarity as to who is specifying and who is designing.

The first option presumes that the specialist contractor is capable and able to produce an effective design. This is subject to the limitations described above and realistically limits the ability to package the wall into contracts for separate layers and components.

The second option places design responsibility with the Architect and/or Main Contractor and thus runs the risk that the Architect is not fully informed about the components and products to detail the interfaces.

An alternative is possible as a variant on the second option above; that is for a consultant or specialist designer to be employed to either:

- design the whole wall;

  or

- coordinate the design/selection of the different layers and components by separate suppliers/contractors.

Many of the larger Main Contractors do now have people with job titles such as ‘Design coordinator’ to ensure that adjoining work packages and their interfaces are properly designed and correctly assembled. However, this practice is not as widespread as it should be and the need for these individuals to be knowledgeable about layered construction is not always realised.

2.2 Wall design

2.2.1 Design priorities

On any project there are many conflicting design drivers and design requirements. Reconciling architectural intent with good, durable and sustainable technical performance requires the wall designer to consider all of the elements of the construction. The architect, structural engineer and building physicist will focus on particular aspects of performance and thus on particular layers or components as shown in *Figure 2.1*. It is important that each designs in the context of whole wall performance.

In *Figure 2.1* elements in normal type will have a primary effect on an aspect of performance; those in italics may have a secondary effect on an aspect of performance. Those elements shown in grey are unlikely to affect that aspect of performance in most built-up walls.

Appearance	**Hygrothermal**	**Structure**	**Robustness**
Rainscreen/render	Insulation	Back wall/frame	Rainscreen/render
Windows/doors	Lining	Rainscreen/render	Lining
Attachments	Cavity	Lining	Windows/doors
Cavity	Structure	Sheathing	Attachments
Lining	Attachments	Cavity	*Structure*
Structure	Windows/doors	Windows/doors	*Sheathing*
Insulation	*Sheathing*	Attachments	Insulation
Sheathing	Rainscreen/render	Insulation	Cavity

Weather	**Fire**	**Acoustic**	**Durability**
Cavity	Cavity	Windows/doors	Rainscreen/render
Rainscreen/render	Insulation	Lining	Attachments
Interfaces	Lining	Insulation	Structure
Windows/doors	Rainscreen/render	Sheathing	Cavity
Lining	Sheathing	*Structure*	Windows/doors
Sheathing	*Interfaces*	*Cavity*	*Insulation*
Structure	*Windows/doors*	*Interfaces*	*Lining*
Insulation	Structure	Rainscreen/render	*Sheathing*

Figure 2.1 - Design concerns

2.2.2 Design considerations

The principal elements of a built-up wall are shown in *Figure 2.2* with the exception of windows and attachments.

In designing, selecting or positioning any element of the envelope there are many things to consider. In *Figure 2.2* it can be seen that the insulation has to be selected on the basis of its:

- thermal conductivity;
- tolerance of water;
- reaction to fire;
- acoustic properties;
- method of retention.

It cannot be selected in isolation as:

- the need for it to be water tolerant will depend on the type of rainscreen joints, cavity width and possible presence of a breather membrane;
- the acoustic properties required will depend on the lining, sheathing or back wall performance;
- the method of retention will depend on the structural form of the wall.

Similarly design requirements are shown for the other elements of the construction. The list of requirements is not exhaustive and it is incumbent on the designer to consider the full range of factors that may influence the design.

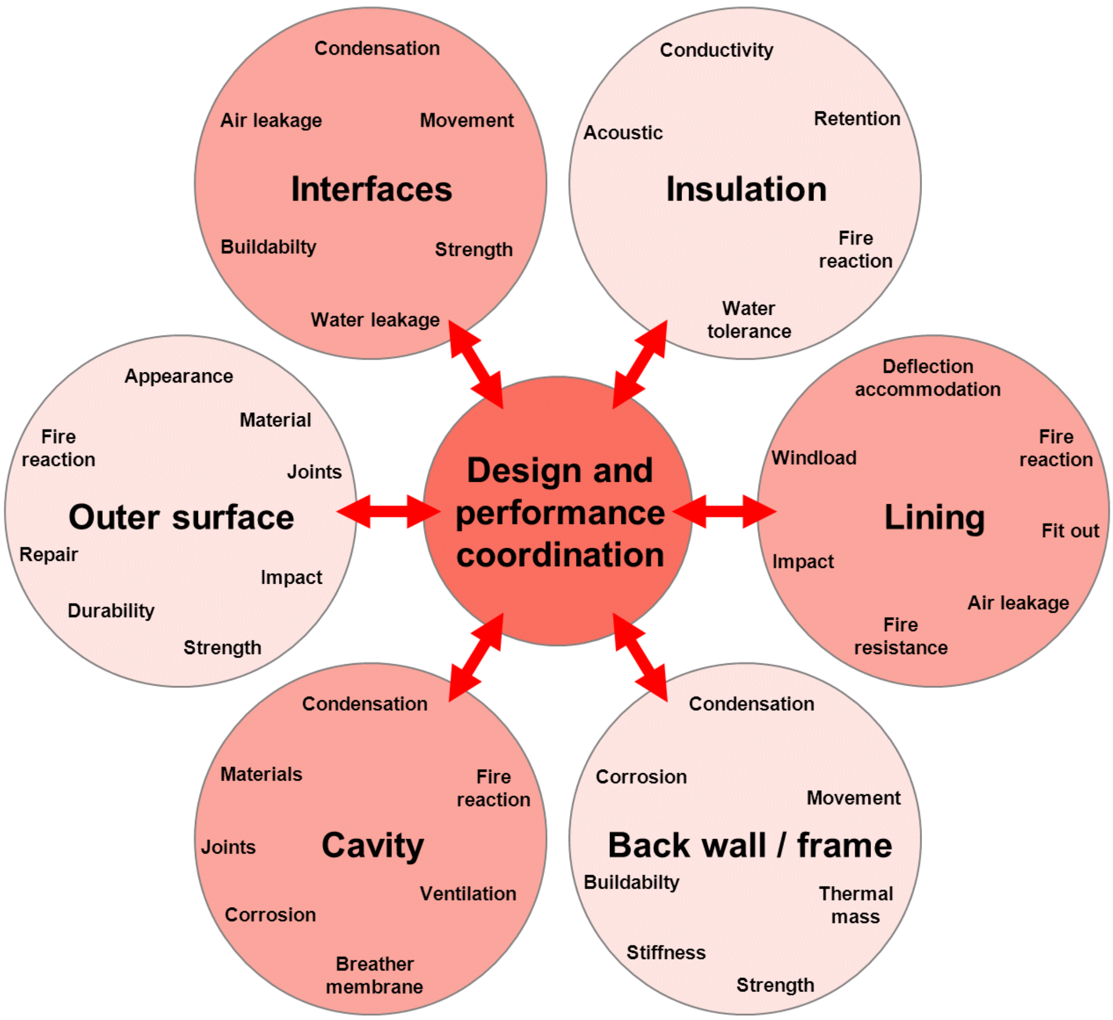


Figure 2.2 - Design coordination

2.2.3 Windows and doors

Windows and doors will be assembled from a system and may either be:

- supplied to the wall contractor for them to incorporate into the wall construction;

  or

- installed at site by the supplier.

In the second case it is important that the window or door surround (pod or separate reveals, sill and head) should be designed and constructed as part of the built-up wall, preferably by the wall contractor. The window or door surround will affect many aspects of the wall performance including:

- reaction to fire;
- weathertightness;
- thermal performance;
- durability.

The interface between any window or door and its surround should be a robust detail that is easy to understand at the construction stage. It should be evident how it should be constructed and should be easy to inspect and/or test. The interface between any window or door and its surround should take account the construction of the window or door; in particular:

- the fixing requirements for the window or door;
- the drainage requirements of any window;
- possible thermal bridging of the window or door frame.

2.2.4 Attachments

Elements or components may be attached to the inner or outer surface of a built-up wall transferring loads to it and potentially reducing aspects of its technical performance. Attachments that are known at the design stage should be incorporated into the design of the built-up wall. Subsequent attachments that might be anticipated, such as fit-out loads applied to the inner surface, should be designed for and any resulting limitations should be included in an O&M manual.

Attachments to the outer surface of a built-up wall may include:

- solar shading;
- photo-voltaic panels;
- signage;
- lighting;
- CCTV cameras;
- satellite dishes.

The reader may have encountered many other components supported from a rainscreen or its supporting structure.

Attachments to the outer surface may affect:

- strength;
- robustness;
- durability.

Attachments to an EWIS require particular attention to ensure that the loads imposed can be safely carried and that the integrity of the waterproof render finish is not compromised leading to water ingress. Advice from the render manufacturer should be sought when attachments are required.

Attachments to the inner surface will be associated with either the initial fit-out or modifications by the occupant.

Attachments to the inner surface may affect:

- air permeability;
- condensation;
- strength;
- robustness;
- watertightness.

2.2.5 Penetrations

Penetrations through a built-up wall may result from:

- ventilation ducts;
- cables;
- pipes;
- balconies;

- canopies.

Penetrations may be full penetrations through every layer between the outer face and inner face, or they may pass only through the inner layers of the wall. It is bad practice to use partial penetrations and route services in the cavity as such constructions are difficult to inspect and remediate.

Penetrations should be designed as part of the built-up wall with appropriate seals and flashings. Penetrations will affect all performance aspects of a built-up wall and particular attention should be given to:

- minimising cold-bridging;
- impact on vapour transmission;
- preventing water leakage;
- preventing air leakage;
- resisting the passage of fire and smoke.

It is unlikely that a mechanical or electrical engineer requiring a penetration through a built-up wall will understand the construction of the wall or the underlying design principles. As a minimum the design of any penetrations should be agreed by the designer of the wall.

Any intended or anticipated penetrations should be considered as part of the wall design from the earliest possible stage. Any subsequent requirements for penetrations should be discussed with the wall designer as soon as they are anticipated as they may not be feasible once the procurement of the built-up wall has commenced.

2.2.6 Design coordination

The architect may focus on the appearance and thus the selection of the rainscreen/EWIS but we can see from *Figure 2.2* that all elements of a built-up wall are interdependent in the way that they contribute to the performance of the whole wall. It is therefore necessary to have a design coordination process to ensure that the components of the wall as a whole deliver the required overall performance.

Design will best be coordinated by having a single designer for all elements of the wall. This may be by:

- appointing a single specialist contractor responsible for delivering the whole wall, or
- appointing a consultant to verify the design and performance, or
- making the architect responsible for coordinating the design or selection of each element.

It is self-evident that the party with the most knowledge and experience is the best party to coordinate the design provided they are appropriately appointed.

2.3 Procurement

2.3.1 Project definition

The procurement has to begin with:

- definition of the architectural intent;
- determination of the overall performance requirements.

These cannot be considered separately or wholly sequentially. Heavy panels such as stone require a very different system of support rails and back wall which will have implications for the insulation and overall thickness of the wall. Some lining systems will be less tolerant of deflections and will require stiffer (deeper) studs or support rails.

It is also important to establish at this stage the Standards and general specification to which the wall will be constructed. The NHBC has Technical Standards that apply to projects on which it places a guarantee. Housing Associations and other Clients also have preferred or bespoke requirements. These may place major constraints on the design of a built-up wall. In particular requirements for:

- cavities;
- drainage;
- ventilation;
- robustness.

2.3.2 Technical appraisal

It is important to identify who will be responsible for pre-contract technical appraisal of the design. This may be:

- the architectural practice;
- the Main Contractor;
- an independent consultant.

At this stage it is important to consider the technical compatibility of:

- required appearance;
- depth of cladding zone;
- outer finish;
- windows and doors;
- interfaces;
- back wall;
- primary structure;
- required cavity and insulation depths;
- balconies, shading devices and other attachments.

The position of each layer of the built-up wall and the performance it is required to contribute to the façade as a whole must also be assessed.

2.3.3 Procurement route

It is advisable to consider the procurement route in parallel with undertaking the technical appraisal. Some designs will require the wall contract to be let as separate packages whereas the Client may perceive a benefit from letting a single contract for the whole wall and having a single point of responsibility for design and delivery of the wall. It is possible to design built-up walls from the outset to be amenable to design and construction as a single package.

The first stage to establishing the procurement route is to identify the package(s) that will be let. This definition of packages should be appropriately detailed to avoid later confusion and should identify responsibility for interfaces and coordination between the separate packages.

A package will ideally comprise a zone of wall such as a whole façade but note that it will still have interfaces with other zones such as adjoining walls, floors, roof and primary structure.

A separate package may be let for the supply and installation of windows and doors. In this case there will be an additional interface with the windows and doors. It is necessary to identify who will be responsible for the design, supply and installation of window and door pods, seals, drainage, avoidance of thermal bridging and fire stopping.

If packages are let for separate layers of the wall then it is essential to fully coordinate the design of the different packages. This requires a knowledgeable and experienced main contractor or a suitable consultant/design house.

The building envelope may be tendered in one of four viable ways:

- Tender the whole building envelope as a single package, assigning the responsibility for co-ordinated design, including the interface with the primary structure, to the successful subordinate contractor.

- Tender the building envelope as several packages, assigning the responsibility for co-ordinated design, including the interface with the primary structure, to one of the successful subordinate contractors.

- Tender the building envelope as several packages, undertaking the responsibility for co-ordinated design, including the interface with the primary structure, to co-ordinate the successful subordinate contractors.

- Tender the whole building envelope as a single package, undertaking the responsibility for co-ordinated design of the interface with the primary structure only, to co-ordinate the successful subordinate contractor.

In setting up a particular procurement route it is important to consider the QA processes. The scope, extent and complexity of appropriate QA processes will vary greatly depending on the number of packages let and the exact form of construction.

Outline quality procedures should be formulated prior to going to tender. They should include:

- technical appraisal of design;
- manufacturing quality;
- quality of installation.

Discussion of the necessary quality procedures may inform the design process. More detailed quality procedures will be established, possibly as the tenders are reviewed, and certainly once the package suppliers have been appointed.

2.3.4 Tender process

When reviewing tenders it is important to remember that the contract is not simply for the supply of goods (the wall) but also usually the supply of design. When considering the merits of one contractor over another the technical capability and capacity should be taken into account.

It is wise to check that tenders have fully understood and accepted the required responsibility for the design and construction of interfaces.

2.3.5 Assigning responsibilities

Whether the built-up wall comprises one package or several packages responsibilities should be assigned at the outset of the contract. This should include identifying the individuals responsible for design and approval in the Architect, Consultant and Main Contractor organisations, as well as all of the package contractors and contractors responsible for adjacent works.

Appropriate routes of communication should also be established. In particular are the separate sub-contractors allowed to communicate with each other or should all communication be channelled through the Architect or Main Contractor.

2.3.6 Acceptance of design

It is not sufficient for a Main Contractor or Architect to accept a design from a specialist contractor without considering how the design coordinates with adjacent packages or other layers of the wall.

This can best be achieved by:

- seeking acceptance of design of one package by designers of adjacent packages:
- employing a package manager or consultant to review design proposals for all packages;

- adopting a concurrent design approach across all specialist contractors.

Processes for checking and accepting design should be defined at the time of letting the contract.

2.3.7 Construction

The construction phase should be considered during the design and tendering stages. Quality procedures appropriate to the scale, complexity and particular features of the wall should be defined at the tender stage. These may include:

- inspection methods and timing;
- acceptance of materials;
- programme hold points;
- requirements for provision of sample panels and components;
- requirements for site testing;
- requirements for third party inspections.

Quality assurance procedures may be incorporated in an agreed method statement or may be described in a stand-alone document.

It is important to have people with the correct skill set and knowledge involved in the construction of the wall.

2.4 Quality

2.4.1 Approach to quality

A built-up wall is likely to be constructed by two or more contractors each responsible for different layers or components such as windows or doors. Responsibility for design and construction of the interfaces should have been assigned at the time the contractors were appointed but all too often this has been overlooked.

Quality assessment procedures have to recognise that constructed work may be concealed by subsequent operations and that disputes may arise between different contractors about the quality of work adjoining their own at interfaces.

The Main Contractor will have primary responsibility for quality procedures. However, these will have to recognise the requirements of other parties which may include:

- client;
- client's consultant;
- architect;
- insurers.

Insurers may include issuers of warranties and guarantees such as the NHBC.

2.4.2 Hold points

It is necessary to set hold points in the construction programmes such that no further work stages are undertaken until the current work stage is completed satisfactorily. For instance the brackets may not be accessible for inspection once the insulation is installed. Clearly in this case the insulation should not be installed until the quality checks on the brackets have been satisfactorily completed. Similarly with wet applied sealant joints it is not possible to ascertain whether the substrates were correctly cleaned and if necessary primed once the sealant has been placed.

Even when work can be checked later in the construction programme it may not be possible to undertake remedial work if access has been denied by later work. For instance a whole building air leakage test should be undertaken after the air barrier is complete but before final fit-out so that access is available to rectify any faulty seals or holes. Removal of means of access such as a scaffold should also be a hold point.

2.4.3 Methods of quality checking

Quality checking may include the following methods:

- direct observation;
- comparison with samples;
- documentation checking;
- testing.

The techniques described below are not an exhaustive list but include the principal methods of checking quality.

Direct observation of the work may be used to verify that:

- the correct materials have been used;
- the materials have been installed correctly:
    - fixing,
    - orientation,
    - laps;
- fastenings are correct (type, size, quantity and torque);
- components are correctly positioned:
    - tolerances have been met,
    - movement is possible where required.

Comparison with samples is used to verify that the appearance of components and finishes are as intended. This may include:

- colour;
- gloss/matt;
- texture;
- flatness.

Documentation checking creates an audit trail and may show:

- manufacturer or supplier;
- grades of materials;
- performances of components;
- CE Marking;
- other quality marks such as British Board of Agrément (BBA) Certification.

Testing may be used to verify performance that cannot be directly observed or performance that relates to the constructed work rather than a single component or detail. Testing may include:

- pull-out tests on anchors and fasteners;
- whole building air leakage tests;
- onsite water testing;
- thermal imaging.

2.4.4 Elements of construction

The quality checks associated with the principal elements of built-up walls are described below. Built-up walls are diverse in their construction and not all of the issues described will apply to a particular wall.

Component/material acceptance is the starting point for quality assurance of the constructed wall. Components and materials should be as described in the design and specification and correctly documented. They should be checked for damage and defects and should be stored appropriately taking account of any manufacturer's instructions.

Back wall construction should be checked prior to fixing of support rails or insulation. The back wall should be checked for:

- line and level;
- fixing of any studs and noggins;
- fixing of any sheathing boards;
- thickness of any sheathing boards;
- fixing of any lining;
- allowance for movement if required;
- sealing of joints;
- corrosion/rot protection, including cut ends.

Brackets and fixings should be checked prior to fixing of support rails or insulation. The brackets and fixings should be checked for:

- position, type, size, quantity and fixity of brackets;
- correct fixings (type, size, quantity, position and torque);
- pull-out strength of fixings in to pre-existing back walls/materials.

Support rails should be checked prior to fixing of insulation. The support rails should be checked for:

- position:
  - level,
  - plumb,
  - plane;
- fastening;
- allowance for movement if required;
- corrosion protection, including cut ends.

Insulation and tapes should be checked prior to fixing of a breather membrane, rainscreen panels or a render. Insulation and tapes should be checked for:

- type;
- thickness;
- completeness;
- fit and seal at penetrations;
- security (to resist wind suction if in cavity).

Breather membranes should be checked prior to the fixing of rainscreen panels. Breather membranes should be checked for:

- type of material;
- orientation of material;
- lap of material;
- damage.

Cavities should be checked where practicable prior to concealment by adjacent elements to check for:

- clearances for drainage and ventilation;
- provision of any specified cavity closures;
- provision of any required fire/smoke stops

Rainscreen panels are best checked against samples provided prior to construction. They should be checked for:

- position and joint width;
- flatness;
- colour;
- gloss or texture;
- correct fixings/fasteners (type, size, quantity, position and torque).

Renders should be checked for:

- correct materials;
- application of reinforcing meshes where required;
- primer or bonding coats as required;
- quality of finish coat:
  - colour,
  - texture.

Interfaces should be checked against construction drawings to ensure:

- correct positioning and fixing of materials and components;
- correct laps and seals;
- correct drainage openings where required;
- use of breathable materials where required.

2.5 Summary of specification, design and procurement process

Figure 2.3 provides a flowchart summarising the key elements of the specification, design and procurement process for built-up walls described above.

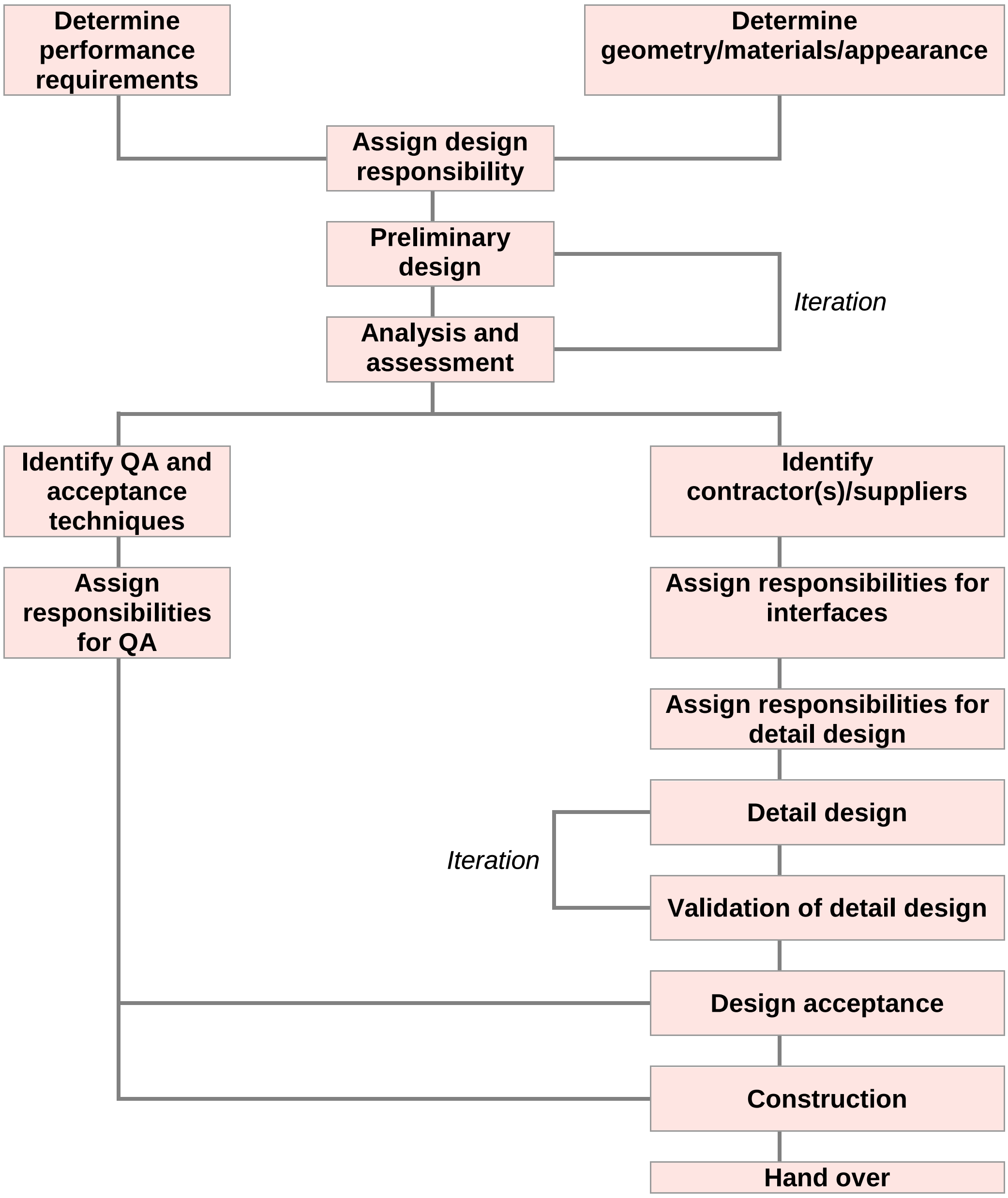


Figure 2.3 – Specification, design and procurement process

3 FORMS OF CONSTRUCTION

This chapter looks at the design principles behind built-up wall construction, including:

- weathertightness principles/basic definitions;
- rainscreen systems;
- externally rendered insulation systems.

The components used in the above systems are described in Chapter 4.

3.1 Principles of weathertightness

In terms of their approach to weathertightness, built-up walls may be described as:

- face-sealed systems;
- secondary defence systems.

3.1.1 Face sealed systems

Built-up walls of this type rely on a single seal at or near the outer surface to prevent water ingress.

Should any moisture get past the outer surface (due to cracking or poor interface detailing) there is often no mechanism to allow that water to get back to the outside.

Prolonged periods of wetting can cause serious damage within the built-up wall, including rotting of timber components (framing for example) and corrosion of metal frames, fixings and fasteners; it may also damage the insulation and the render.

In addition, depending on the materials used as the outer layer of the wall, moisture vapour migrating through the wall from the internal environment may be trapped, resulting in possible interstitial condensation problems.

Systems which rely on a single seal for providing weathertightness demand high standards of installation and maintenance. A drained cavity behind the outer seal can be incorporated into the design of the wall which may help to remove any moisture penetrating into the wall.

Face sealed systems are only applicable to EWIS, and are generally not recommended. See Section 3.3.2.

3.1.2 Secondary defence systems

The secondary defence or two-stage approach to weather resistance has been used for many years. In a secondary defence system, the rain and air barriers are separated by an air cavity.

The outer surface provides the major barrier to rain penetration meaning that the inner seal, the cavity face of the backing wall, is kept relatively dry. If this surface is protected from wetting, water cannot leak to the interior.

A drained cavity provides a means of escape for water that passes the outer surface of the wall.

Secondary defence systems may be defined as ‘drained-and-ventilated’ or ‘pressure-equalised’ and these are discussed in Section 3.2.4.

All rainscreen walls by definition employ a secondary defence system for weathertightness. The method can also be used in EWIS (see Section 3.3.2).

3.1.2.1 Drained principle

Drained systems are secondary defence systems that allow water to drain from between the inner and outer seals through suitably protected openings in the outer face of the wall.

3.1.2.2 Drained-and-ventilated principle

Drained-and-ventilated systems are provided with ventilation openings in addition to the drainage openings. This combination of openings allows air to circulate and dry the cavity between the inner and outer seals. This is discussed further in Section 3.2.4.1.

3.1.2.3 Pressure-equalised principle

The drainage and ventilation openings are enlarged to ensure that the air pressure behind the outer seals or open joints nearly matches that of the external wind pressure. This is discussed further in Section 3.2.4.2.

The principle of pressure equalisation can be applied to minimise water leakage past the outer seal of a secondary defence system.

3.1.3 Externally ventilated cavities

Cavities are used as part of a secondary defence against water penetration, and so are in this section. Cavities may also be used for other reasons, such as for thermal performance, described in Section 6.7.8.

The following classifications are taken from BS 5250 - *Code of practice for control of condensation in buildings* and from BS EN ISO 6946 - *Building components and building elements – Thermal resistance and thermal transmittance – Calculation method*.

3.1.3.1 Vented air space (BS 5250)

Cavity or void that has openings to the outside air placed so as to allow some limited, but not necessarily through, movement of air.

3.1.3.2 Ventilated air space (BS 5250)

Cavity or void that has openings to the outside air placed so as to promote through movement of air.

3.1.3.3 Unventilated air layer (BS EN ISO 6946)

An unventilated air layer is one in which there is no express provision for air flow through it.

An air layer having no insulation between it and the external environment but with small openings to the external environment shall also be considered as an unventilated air layer, if these openings are not arranged so as to permit air flow through the layer and they do not exceed:

- 500 mm^2 per metre of length (in the horizontal direction) for vertical air layers;
- 500 mm^2 per m^2 of surface area for horizontal air layers[1)].

Note - Drain openings (weep holes) in the form of open vertical joints in the outer leaf of a masonry cavity wall are not regarded as ventilation openings.

3.1.3.4 Slightly ventilated air layer (BS EN ISO 6946)

A slightly ventilated air layer is one in which there is provision for limited air flow through it from the external environment by openings of area, A_v, within the following ranges:

- 500 $mm^2 < A_v \leq 1500$ mm^2 per metre of length (in the horizontal direction) for vertical air layers;
- 500 $mm^2 < A_v \leq 1500$ mm^2 per m^2 of surface area for horizontal air layers[1)].

3.1.3.5 Well ventilated air layer (BS EN ISO 6946)

A well ventilated air layer is one for which the openings between the air layer and the external environment exceed:

- 1500 mm^2 per metre of length (in the horizontal direction) for vertical air layers;
- 1500 mm2 per m2 of surface area for horizontal air layers[1)].

[1)] For vertical air layers the range is expressed as the area of openings per metre length (in the horizontal direction). For horizontal air layers it is expressed as the area of openings per square metre area.

3.1.4 Water leakage mechanisms

There are a number of mechanisms by which water may leak through a joint (*Figure 3.1*). They are:

- gravity flow;
- pressure flow;
- kinetic flow;
- surface tension;
- capillary flow,
- pumped flow;
- air-supported droplets.

Gravity flow is where a drop of water moves under the influence of its own weight. The physics of gravity flow demand that there is sufficient weight to overcome surface tension forces. Gravity flows can be discouraged by providing steps and upward slopes in the path of the flow, although care should be taken not to create regions where water can collect.

Pressure flow can occur as the result of a pressure difference across a body of water - it is usually necessary that the water forms a continuous film across the joint, otherwise a sufficient air pressure differential cannot be generated to move the water. Pressure flows can be discouraged by preventing a continuous film of water from forming, and this requires that the joint is sufficiently wide that any film of water collapses under its own weight. However, if water cascades over the joint opening then a continuous film may be generated and blown into the joint by air pressure fluctuations. This can be discouraged by distancing the stream of water from the joint opening with a suitable projection of the outer surface or recessing of the joint.

Water leakage by this mechanism may be limited by:

- pressure equalisation,
- the provision of well drained joints,
- a high upstand in the joint.

Kinetic flow can occur if water droplets approach the joint at a sufficiently high speed that they are carried through the joint by their own momentum. Suitable arrangements of baffles, preventing a direct passage through the joint will stop kinetic flows.

Surface tension attracts water to surfaces. This allows a droplet of water to run along a horizontal surface, unless some step is provided in the path of the water to encourage the water to separate from the surface. A ‘drip’ is often used on the edge of any overhanging feature to prevent water from running back along the underside of the overhang. With a timber sill a groove is cut in the underside. With an aluminium or plastic extrusion, a nib is included on the underside of a sill.

Capillary flow may occur due to surface tension, but this requires a narrow joint, so that the mass of water is sufficiently small that it can move under the influence of the (low) surface tension force. If the joint is wide enough to prevent the formation of a continuous liquid film then capillary flow cannot occur. Where a film of water does occur then pressure driven flow may occur.

The amount of water that can pass a joint in this way is limited by the narrowness of the joint. However, water ingress into the joint may cause local damage such as mould growth or corrosion within the joint.

Pumped flow occurs if a film of water is trapped between two surfaces which undergo a relative motion. Pumping is prevented if the film of water cannot form in the first place or if the movement is restrained. Again the joint should be sufficiently wide that a film of water cannot form.

Air-supported droplets can be carried by a fast moving flow of air through a joint (this is different to kinetic flow in that the droplets may be very small and possess little momentum). This phenomenon can be prevented by slowing the air, such that the water droplets fall under gravity and can be drained away, or by stopping the flow of air by using some form of draught-strip. The air movements may be slowed by adopting a pressure-equalised design. Alternatively, the joint can be shaped as a labyrinth, forcing the air stream to change direction, such that the droplets impinge on some convenient surface from where they can be drained.

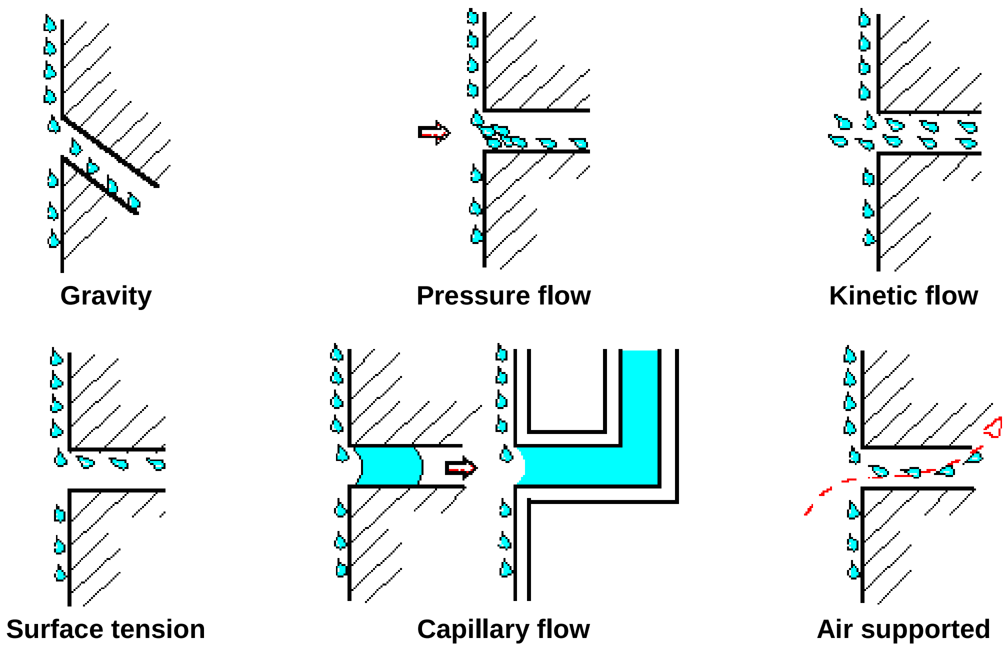


Figure 3.1 - Water leakage mechanisms

3.2 Rainscreen construction

The key features of a rainscreen wall (*Figure 3.2*) are:

- an outer skin of panels, the rainscreen;
- an air gap, at least 25mm deep;
- an insulated backing wall that controls air leakage.

The rainscreen shields the backing wall from direct rain. However, depending on the nature of the joints between panels some water penetration may occur. The air gap and airtight backing wall combine to limit this penetration. The performance of rainscreen systems thus depends upon the particular way in which joints, air gap and backing wall are created.

3.2.1 Ventilation of rainscreen cavities

All rainscreen cavities should be ventilated to remove moisture that arises from:

- water penetrating the rainscreen;
- moisture migrating from the inner surface of the wall;
- condensation.

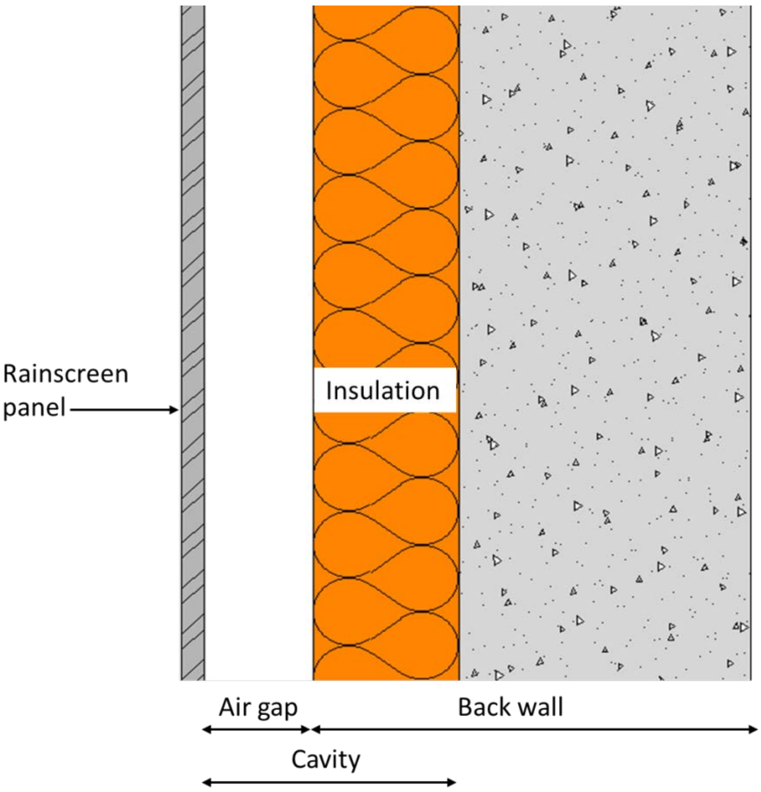


Figure 3.2 - Rainscreen definitions

The required air gap will depend on:

- the type of secondary defence (drained-and-ventilated or pressure-equalised);
- the type of joint between the rainscreen panels (Section 3.2.2).

It is particularly important that cavities are maintained around framing members, rails and supports.

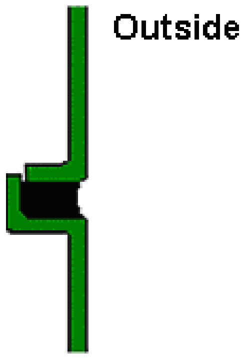
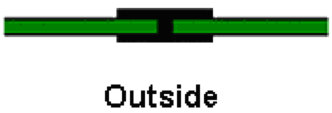
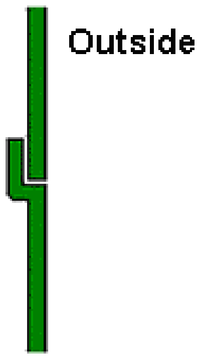
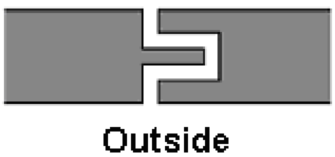
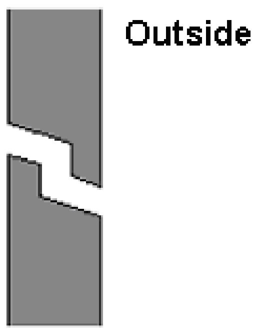
3.2.2 Rainscreen joints

It is a feature of rainscreen systems that joints do not need to be sealed, because water penetration is managed by the combination of the behaviour of the air gap and the backing wall.

The panel joints used will depend upon the:

- method of secondary defence used (drained-and-ventilated or pressure-equalised);
- panel type/material;
- forming limitations,
- architectural considerations.

The panel joints may be any combination of those shown in *Figure 3.3*.

Joint type	Vertical detail	Horizontal detail
Sealed Joint Joints comprising a gasket, wet applied sealant or sealant tape to provide an air and water seal. Note some sealant foam tapes allow passage of air and water vapour. Sealed joints may break down over time allowing water leakage via pressure difference and capillary action.		
Closed joints Joints comprising close fitting components. Gaps are only large enough to allow assembly and too small to allow water entry. Note: capillary action may draw water into the joint and lead to corrosion. Closed joints are not sealed		
Labyrinth joints Joints intended only to prevent the ingress of water; the panel edges are shaped to prevent direct water entry. The joints are too wide for capillary action. The tortuous path means that air-borne water cannot pass straight through the joint, and is deposited on the faces of the joint. Water may track down vertical joints and reach the back of the panel. If horizontal joints become flooded, pressure difference may force some water through the joint.		

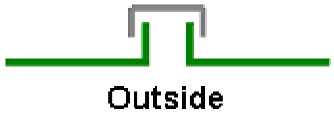
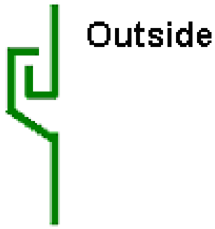
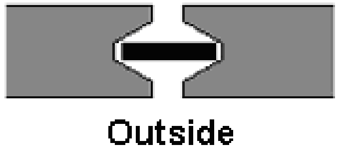
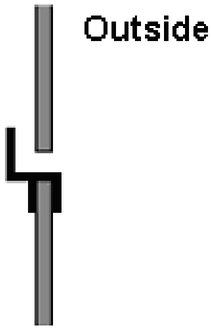
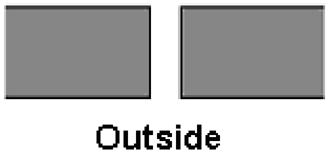
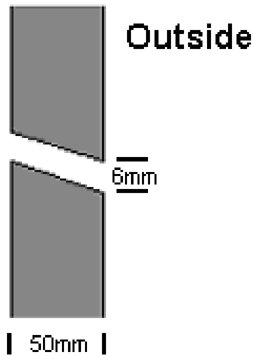
		
Baffled joints Joints including an additional component in order to create the equivalent of a labyrinth joint. These are normally only used where it is not possible, or economical, to form a labyrinth on the edge of a panel.	 For thicker panels	 For thinner panels
Open joints Joints that comprise two panels with no geometrical barrier to water ingress. Passage of water through these joints is reduced by pressure-equalising the cavity behind the joint. Some water will pass the joint and has to be drained from the cavity. These joints are used where other joints are impractical, for instance with natural stone panels. The passage of water is dependent on the geometry of the joint.		

Figure 3.3 - Rainscreen panel joints

Where it is intended that a joint between rainscreen panels should be 'open' (i.e. a labyrinth, baffled or open joint) it is essential that it large enough so that it does not become blocked. It is recommended that the minimum joint opening shall be limited according to the following criteria:

- all joints to have an absolute minimum opening of 6 mm, to permit free drainage;
- joints which are required to remain unblocked to have an opening of 10 mm.

Where joints have a minimum opening of less than 10 mm the joints may become blocked by snow or ice, which will compromise the pressure equalisation of the rainscreen cavity.

The thickness of the panel should be considered when thinking about the minimum required joint width, with joints which are narrow compared with the thickness of the panel more likely to get blocked than joints which are wider.

3.2.3 Rainscreen cavity widths

The air gap immediately behind the rainscreen should have a minimum dimension as shown in *Table 3.1*, taken from the CWCT *Standard for Systemised Building Envelopes*. The required cavity width will primarily depend on the:

- panel type;
- joint type;
- secondary defence system (drained-and-ventilated or pressure-equalised);
- support system.

In general, the required width of the cavity is related to the amount of water that can be expected to pass the outer panels of the rainscreen. This is to try and ensure that any water passing the rainscreen flows down the back of the panels without wetting the insulation or the backing wall.

Joint type	**Air gap**	**Typical panel type**	**Design joint to:**
Sealed joints	38 (25) mm minimum[1]	Any	Suit the sealant system
Closed joints	38 (25) mm minimum[1] Drained-and-ventilated	Any	Allow for movement and tolerance
Labyrinth joints	38 mm minimum Drained-and-ventilated or pressure-equalised	Pressed metal Terracotta	Allow for movement and tolerance and provide the required gap width
Baffled joints	38 mm minimum Drained-and-ventilated or pressure-equalised	High pressure laminates GFRP Fibre cements	Allow for movement and tolerance and provide the required gap width
Open joints	50 mm minimum[2] Pressure-equalised only	Natural stone	Allow for movement and tolerance and provide the required gap width

Table 3.1 - Joint and cavity combinations for rainscreen

[1] *Although 25mm is recognised as being the minimum required cavity width for panels with sealed or closed joints, best practice would be to have a cavity which is 38mm. A wider cavity will give a more robust system by offering greater protection to the insulation/backing wall should water pass the panels. Specifying a wider cavity will also help ensure that the as-built cavity, taking account of tolerances etc., will be a suitable width.*

In reality wider cavities have become standard, in part due to tighter thermal regulations and the desire to move the cladding support rails outside of the insulation layer so that it does not form a thermal bridge.

[2] *This value may be relaxed for close butt joints if verified by test.*

The minimum allowable air gap shall not be reduced by more than fifty per cent at fire barriers and support rails. This is to ensure that that no blocking of the cavity occurs. This could be achieved by using intumescent fire barriers. Alternatively, the cavity could be completely closed at fire barriers and ventilation openings provided above and below the closer. This will be discussed in greater detail in Section 6.6.

It is important that the designer and contractor are aware that the minimum air gap is the absolute minimum. The joint widths given in *Table 3.1* are minimum as constructed values. They should generally be specified at a greater width to allow for construction tolerances.

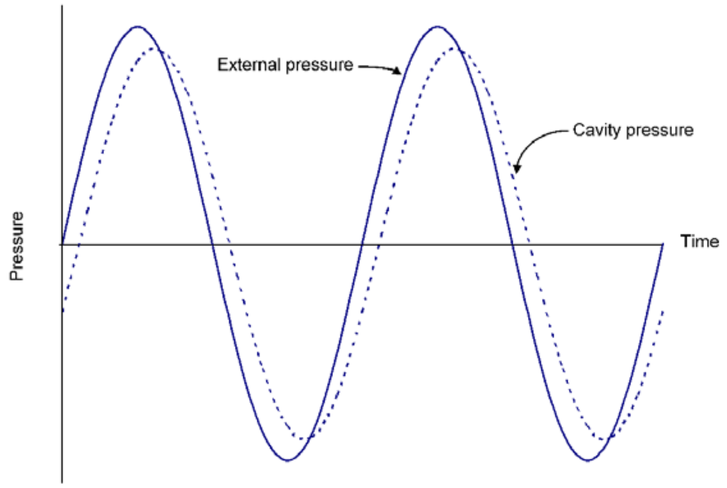
3.2.4 The air gap

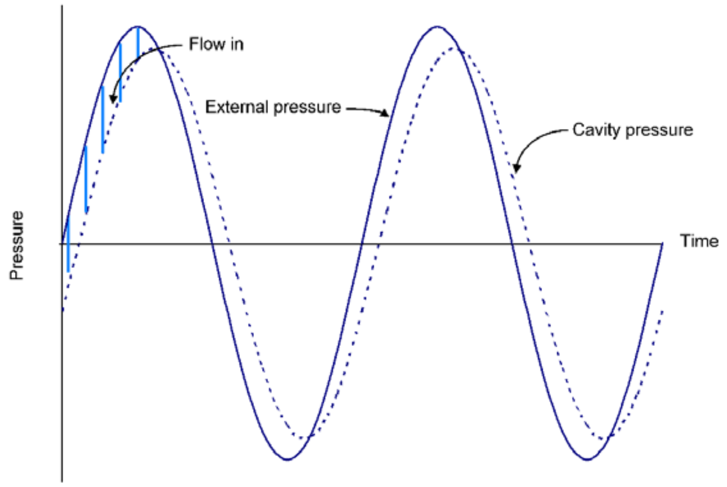
The air gap of a rainscreen wall may be treated in one of two ways:

- drained-and-ventilated;
- pressure-equalised.

In practice all cavities will experience a degree of pressure moderation, which will aid the water penetration resistance of the wall. Full pressure equalisation with zero net pressure difference across the rainscreen can never be achieved (*Figure 3.4*), however following the rules given in Section 3.2.4.2 will give the greatest degree of pressure equalisation consistent with economic and weathertight design. It should be noted that a pressure-equalised wall is still drained-and-ventilated.

In practice the pressure in the rainscreen cavity lags behind the external wind pressure, resulting in periods where the pressure is lower in the cavity and air/water is forced in, and periods where the cavity pressure is greater than the external, and air/water is forced out.





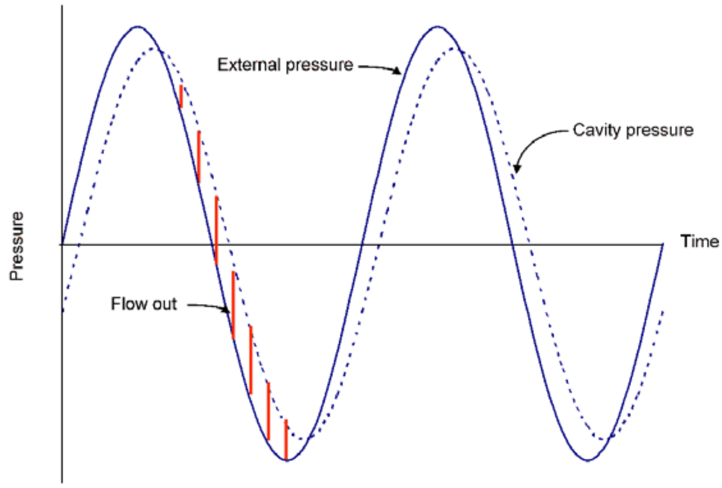


Figure 3.4 - Pressure equalisation in practice

3.2.4.1 Drained-and-ventilated

The air gap is left continuous, perhaps running over the entire facade. However artificial cavity barriers may be introduced and the effective air gap is limited in height or width by firestops or closers around penetrations.

With this approach water penetration is drained outwards, and air movement is encouraged to dry out any water which enters the air gap.

To enable this ventilation, the rainscreen may have all joints left unsealed or open, or may only have unsealed joints at the top and bottom of the air gap (*Figure 3.5a*).

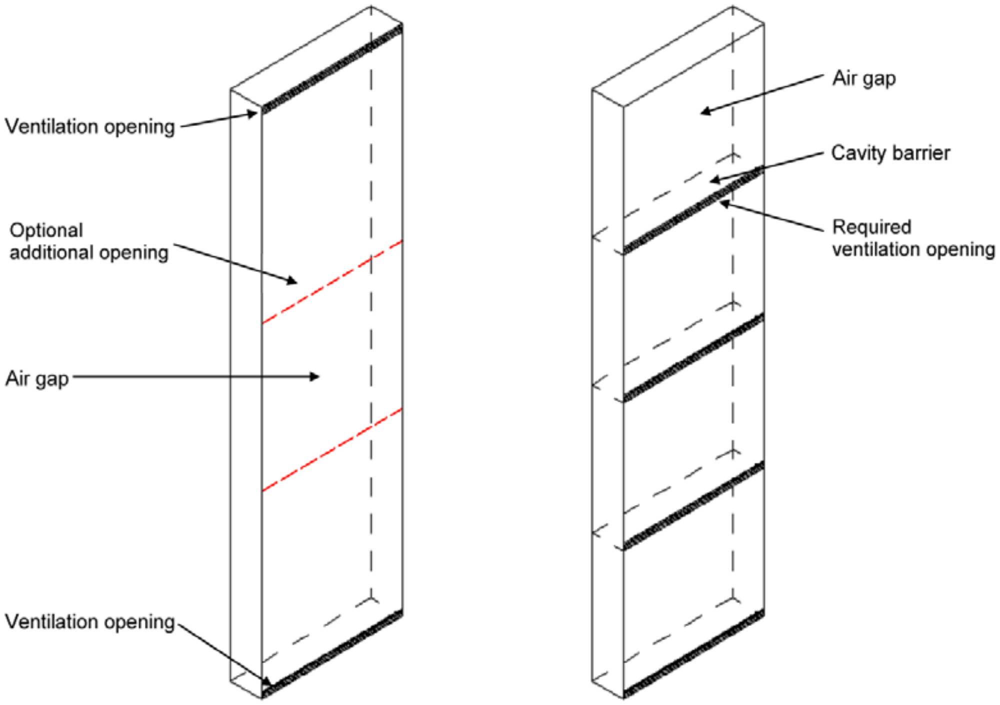
Care should be taken regarding cavities which extend around the corner of buildings. Due to the pressure differences on the adjacent facades this would result in large air movements within the cavity which may also carry significant amounts of water. In addition, the flow of air may cause noise problems for the building occupants.

Best practice therefore is that cavities should be closed at or within 300 mm of the corners of a building. This may be achieved by default with vertical cladding rails or alternatively an additional component may be required.

3.2.4.2 Pressure-equalised

The air gap is divided into compartments which may be no more than one panel wide or high, but normally encompass several panels.

At least one joint at the perimeter of the panel is left unsealed or open, to enable pressurisation of the air gap, which then limits water penetration by virtue of reduced pressure difference across the joints (*Figure 3.5b*).



a) Drained-and-ventilated **b) Pressure-equalised**

Figure 3.5 - Air gap

The degree of pressure equalisation that is achieved depends upon the ratio of ventilation aperture area to the cavity volume, and the degree of airtightness that is achieved for the cavity dividers and the back wall.

The following guidance is taken from the CWCT *Standard for Systemised Building Envelopes*. A rainscreen shall be considered to be pressure-equalised if the following conditions are met:

- the air permeability of the rainscreen is greater than ten times the air permeability of the air barrier, and;
- each compartment is vented with openings of adequate area for the volume of the compartment:
  - o in general, if the cavity volume (m^3) is less than eighty times the vent area (m^2) then pressure-equalisation may occur, based on National Research Council Canada document '*Pressure-equalisation performance of a metal and glass curtain wall*'. For a storey height panel, a continuous 10mm horizontal joint would be more than sufficient to achieve this;
- the cavity is adequately compartmented (*Figure 3.6*):
  - o by a horizontal cavity closer at each floor level, and
  - o by a horizontal cavity closer within 1.5 m of a parapet, and
  - o by vertical cavity closers at no more than 6.0 m centres, and
  - o by vertical cavity closers at no more than 1.5 m centres within 6.0 m of a corner, and
  - o by a closer as near as is practical and not normally more than 300 mm from the finished outer corner.

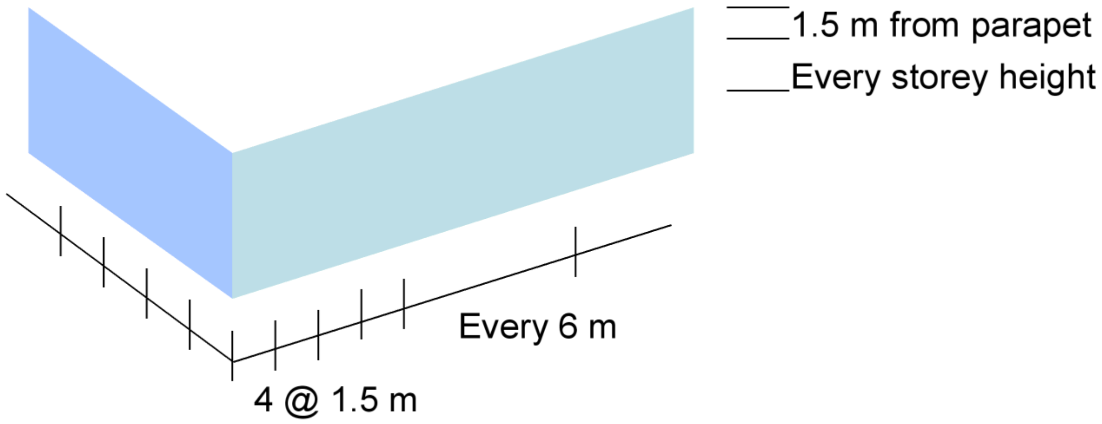


Figure 3.6 - Compartment requirements for pressure equalisation

Partial compartmentation can be beneficial. It will not give full pressure-equalisation but will moderate the cavity pressures, and therefore reduce water penetration.

It should be noted that pressure-equalised rainscreens are more difficult and expensive to construct than a drained-and-ventilated system, and in reality it is never fully achieved. Pressure equalisation may be specified without the consequences of that decision being fully understood.

If pressure equalisation is required it is vital that appropriate decisions are made early on, considering:

- the cost and additional complication of achieving pressure equalisation;
- the architectural implications, requiring additional joints either side of cavity barriers etc.;
- who is responsible for ensuring pressure equalisation if the different wall packages are split?

It should be noted that the technique of pressure equalisation is widely used in window and curtain wall frames, where cavity volumes and ventilation areas are easier to define and implement.

3.3 Render systems

'Modern' render systems have been in use in continental Europe since the 1960's, and were introduced in the UK in the late 1970's.

This document will concentrate on insulated render systems (EWIS) and recommends that a drained and/or vented cavity is present in most cases, see Section 3.3.2.

Early use of EWIS was predominantly in the low rise refurbishment market. This allowed buildings that were structurally sound but deficient in other areas to be upgraded relatively quickly and economically transforming them in terms of both the appearance and the performance, in particular the thermal performance.

External insulation is well suited to this type of application, however can create difficulties at window reveals and eaves overhangs etc. The original wall is likely to be traditional masonry or precast concrete construction and be inherently weathertight (air and water). This provides a stable surface on which to apply the insulation and render.

With new build construction and high rise refurbishment, the potential risks are greater, particularly with lightweight stud walls. Such walls will have greater flexibility and movement than traditional construction, which must be accommodated by the render. This can be done; however, it is vital that the back wall details are known at the early design stage so that the system can be detailed correctly. A longer life may be required for new build construction than a refurbishment project, which must be properly considered during the design, procurement and construction process.

Issues have occurred in the past because people have used the external render to provide the complete weatherproofing of the wall. The general approach should be that the back wall is weathertight, all windows etc. sealed into the openings and then the insulation and render are added.

Another issue which may occur is that the render system is used as a way of hiding other problems within the wall, such as cracking and water ingress. This may result in the render subsequently cracking; often the render system is thought to be at fault, whereas the actual issue lies elsewhere within the back wall.

3.3.1 General forms of construction

Render is normally applied directly to the outer face of insulation which is fixed (mechanically or with adhesive) to the back wall. Alternatively, the render may be applied to boards fastened to the support wall or to rails on it.

3.3.1.1 Render on insulation systems

EWIS may be categorised by the type of support wall that is used. The support/back wall may be categorised as:

- solid wall, or
- framed wall.

And then further categorised as:

- Continuous, or
- Infill between floor slabs.

If the back wall contains movement joints, these should be carried through the render. This is discussed further in Section 3.3.2.

Solid back walls are typically constructed from blockwork or concrete (*Figure 3.7*). A solid back wall will generally be stiffer than a framed wall, resulting in less movement. This in turn may lead to less cracking of the external render and inner air barrier.

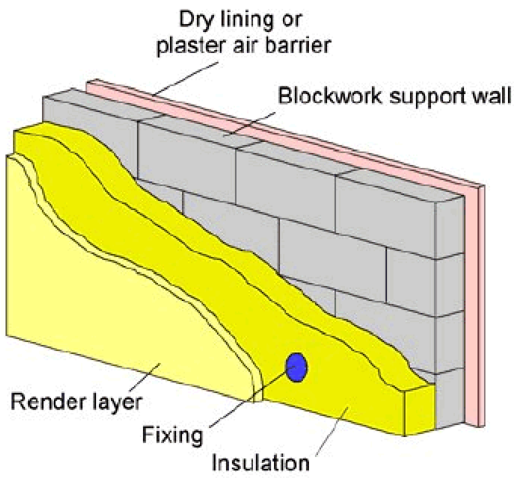


Figure 3.7 - Render on insulation system on a solid support wall

A solid support wall will offer some resistance to moisture diffusion through the wall and a vapour barrier may not be needed. The moisture movement through built-up walls will be discussed further in Section 6.8.

Framed support walls comprise metal or timber studs supporting a dry lining system on the inside (*Figure 3.8*). The outer face normally comprises cement particle boards as sheathing to which the insulation is fixed.

With framed support walls there will be greater out-of-plane deflection of the wall. There may also be in-plane movement. If the deflections are too great the render, the air barrier or both may be cracked.

With framed support walls it is important to consider whether a vapour control layer is necessary, and if so where it is positioned.

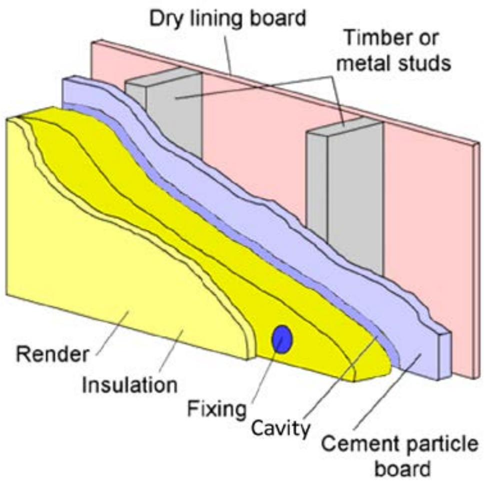


Figure 3.8 - Externally rendered cladding system on a framed support wall

3.3.2 Cavity construction

EWIS have been constructed with or without a cavity. A cavity may be provided in order to introduce a secondary defence against water ingress. Such a cavity should be drained to the outside in order to remove any moisture present. Care must be taken to ensure that the openings between the cavity and the external environment are not too great otherwise the U-value of the wall will be impaired (see Section 6.7.8).

Insurers such as the NHBC require cavities to be incorporated into walls of framed construction, which has an impact on insulated render systems. The requirements depend on whether the frame is timber or metal.

A potential disadvantage of providing a cavity is that, depending on the method of construction, the insulation is not fully supported and will therefore flex/move more due to wind load and/or impact. This may result in cracking of the render and create a potential path for water ingress. This is of particular importance where people would have direct access to the façade, and a more robust form of construction may be used for the ground floor of the building. A vented/ventilated cavity will also reduce the thermal performance (U-value) of the wall.

There are several ways of providing a cavity within an EWIS. In most cases the cavity will be between the sheathing and the insulation. These include using two layers of sheathing board with a 'top hat' section between them to create the cavity (*Figure 3.9(a)*) or using a shim between the fixing rail for the insulation and the sheathing board (*Figure 3.9(b)*). Alternatively, manufacturers can supply proprietary fixings that give a fixed gap between the insulation and the sheathing board (*Figure 3.10*). Such fittings have the advantage of ease and speed of installation together with adjustability to allow for uneven surfaces and construction tolerances to ensure the wall is in-plane before the render coat is applied.

Figure 3.11(b) shows an alternative method whereby the cavity is between the insulation and a second board that carries the external render (essentially rainscreen construction). This method is usually more complicated and expensive to build.

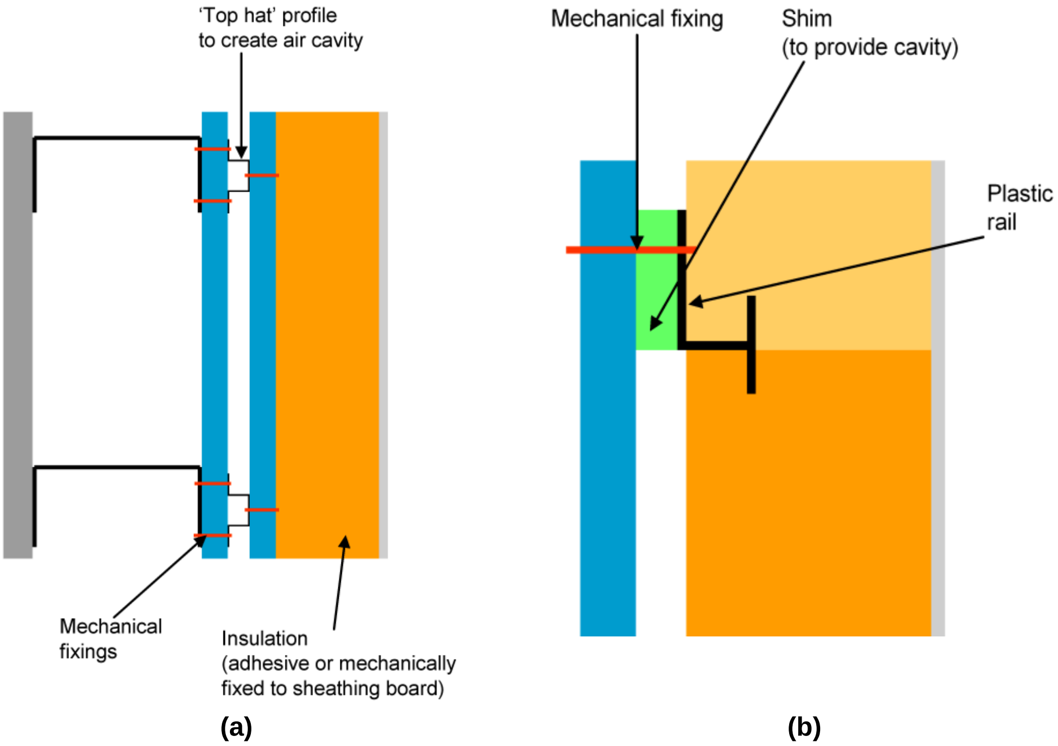


Figure 3.9 - Fixing insulation with a cavity

Figure 3.10 - Proprietary insulation fixings (RotoFix Plus, ©STO)

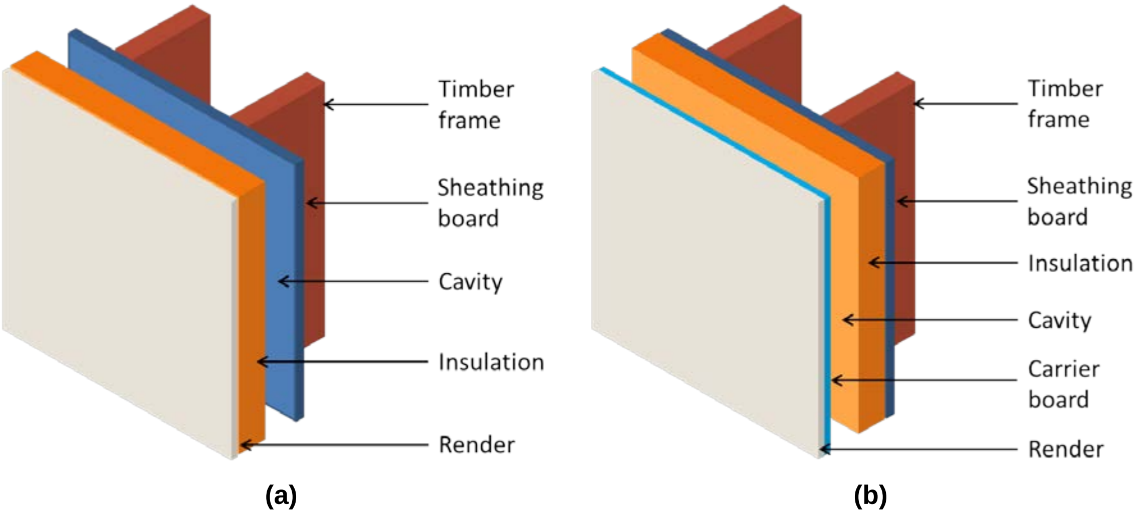


Figure 3.11 - Cavities in timber frame construction

3.3.2.1 Framed back walls

Framed walls will generally be subject to greater movements than solid walls and therefore the risk of the render cracking and subsequent water penetration is higher. Furthermore, a framed back wall has a lower resistance to water penetration and the materials used tend to be less tolerant of wetting. Therefore, additional protection by means of a drained cavity is required.

CWCT always recommends that there is a cavity with a framed back wall.

A small number of EWIS have Agrément Certificates for use on framed back walls. The majority of those that do require a drained cavity behind the insulation with a steel framed back wall, or a drained and vented cavity (with a breather membrane on the cavity face of the sheathing) with a timber framed back wall. See below for further details.

3.3.2.1.1 Timber frame

In the case of timber frame, the NHBC requirements are for a drained and vented cavity with a minimum width of 15mm between the cladding and the sheathing. This is in response to the problems that occurred with water ingress in timber framed construction in North America and New Zealand, where there was widespread failure of face-sealed systems see *Figure 3.12*. The drainage gap allows any water to be channelled safely away and the ventilation controls the moisture content of the timber frame.

Figure 3.12 – Failure of an external insulation system on a timber frame with no cavity, New Zealand (less than 10 years old)

An important consideration when meeting these requirements is the thermal performance of the wall. Depending on the position of the main insulation layer, the introduction of a vented cavity can result in a significant reduction in the thermal performance (increase in the U-value). For these reasons EWIS are not commonly used with timber framed backing walls.
This will be discussed in more detail in Section 6.7.8.

3.3.2.1.2 Metal frame

In the case of steel frame construction, the NHBC require a drained cavity of at least 15mm, although a wider cavity may be needed depending on the rigidity of the components of the system used.

For steel framed back walls it is not necessary for the cavity to be vented/ventilated, however arrangements are required to ensure that any water which gets in will be safely channelled out with trays and weep holes are required. Because the cavity does not require any ventilation provision, meeting the required U-value is more straightforward.

3.3.2.2 Solid back walls

Solid back walls, formed from masonry or concrete for example, are inherently more stable than framed back walls, and more tolerant of local dampness. It could therefore be argued that the consequence of water reaching the back wall is less significant. In addition, if the insulation is in full contact with the back wall there will be less movement of the render which will therefore be less prone to damage. This does not however mean that cavities are not recommended for certain types of solid back wall.

Key considerations in determining whether a cavity is required include:

- the quality of the back wall;
- the type of solid back wall;
- the height of the wall.

Solid walls which are designed to be exposed should be constructed from suitable materials with mortar joints being continuous and of an appropriate type and quality (struck or bucket handle for example). A solid back wall of this nature would be far more water resistant than one constructed from lightweight, permeable blocks, with basic mortar joints, which may be used as a back wall for both low- and high-rise buildings.

Solid back walls may broadly be categorised as being load bearing/continuous or infill between floor slabs, *Figure 3.13*.

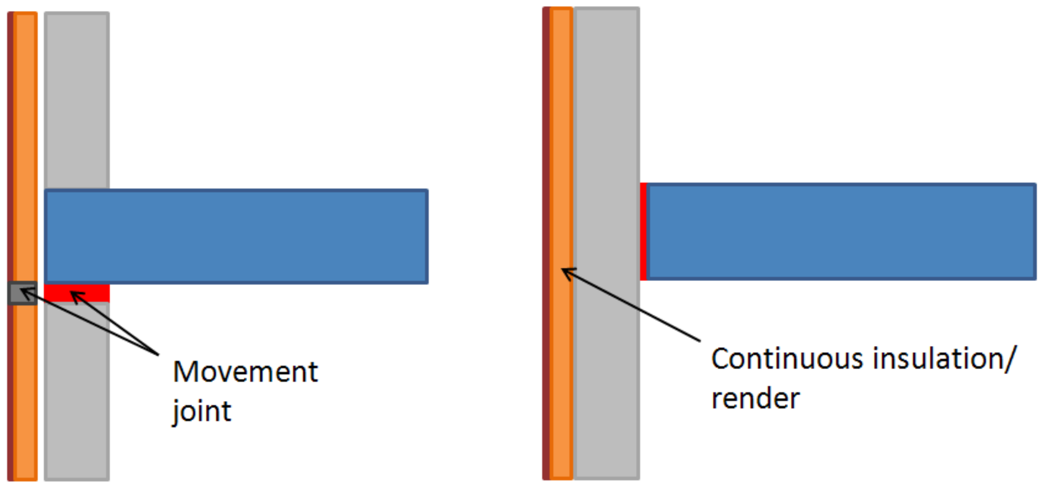


Figure 3.13 - Infill back wall (left), continuous back wall (right)

Figure 3.14 – Movement joints in EWIS

An infill back wall between floor slabs will require a movement joint at the head of the wall to allow for deflection of the floor slab above. This movement joint should be replicated in the external insulation and render (*Figure 3.14*), and as such will provide a potential weak point where water leakage may occur. Infill solid back walls contain further features which can affect the weathertightness. Interfaces with columns, beams and wind posts will all provide discontinuities where movement may occur and mortar joints may fail allowing any water present to penetrate into the back wall.

The solid back wall of a high-rise residential building is more likely to be an infill wall between floor slabs. The consequences of failure for a high-rise building are much greater than those for low-rise, due in part to the greater area of wall and also the requirements for external access. Any extensive repairs and maintenance are further complicated due to having to deal with multiple individual dwelling owners (leaseholders).

A continuous solid back wall without movement joints will allow for an uninterrupted layer of insulation and render to be applied. This means fewer joints, more straightforward installation and therefore potentially less risk of water penetration.

The size of the wall is also important. A large area of external insulation is likely to have the render applied over a number of days. This is likely to necessitate the use of additional profiles as 'day-joints' giving the applicator a clean edge to work to, and to start from the following day. Again this introduces a potential weak spot for water ingress if the joints fail over time.

Refurbishment of existing dwellings forms a large part of the EWIS market. A key consideration for such projects is the condition of the back wall. An EWIS is intended to improve the thermal performance and appearance of a dwelling. It should not be used to improve the weathertightness of the existing wall. It must be recognised that in some refurbishment cases the back wall will not be watertight, and the design of the external insulation system should take this into account.

Other factors which are important in establishing the need for a drain cavity include:

- complexity of the façade;
- exposure of the façade – location, height of building;
- consequences of failure;
- ease of replacement/remedial work;
- ownership of the building (single or multiple ownership).

Based on this approach the risk of water ingress (and therefore the requirement to incorporate a drained cavity) is increased for:

- tall buildings where the exposure is greater;
- non loadbearing walls (infill walls) where movement joints are required at floor levels;
- walls containing a large number of windows, balconies and other features and penetrations;
- back walls which are not weathertight.

This approach would allow insulation to be applied directly to a solid back wall which is:

- low rise;
- load bearing;
- appropriately designed so that it is inherently weathertight and durable (new construction);
- weathertight generally (refurbishment).

CWCT recommends that:

Solid, load bearing, weathertight back walls up to two storeys high may be constructed without a cavity.

Solid back walls greater than two storeys high require a drained cavity.

A number of external insulation systems have Agrément Certificates which allow the insulation to be directly fixed to a solid back wall without a drained cavity. These are often viewed as a guarantee of performance, durability and quality under all circumstances. However, the Certificates are very specific in terms of their scope, and contain a number of caveats regarding their application.

With regard to maintenance, repair and durability, the following phrases are commonly used in Certificates:

- ‘regular checks should be made on the installed system’;
- ‘it is essential that the insulation systems are installed and maintained in accordance with the conditions set out in this Certificate’;
- ‘system will provide a degree of protection against rain ingress’;
- ‘ensure that walls are adequately weathertight prior to its application’;
- ‘necessary repairs should be carried out immediately’;
- ‘cracks in the render exceeding 0.2mm must be repaired’.

All of the above suggest that the condition of the external render is critical to the long term performance and durability of an EWIS. It must be recognised that whilst the render may be conceived as being waterproof, this cannot be guaranteed and there may be water ingress due to:

- deterioration over time;
- poor workmanship;
- cracks due to impact/building movement etc.

Experience tells us that the requirements for regular inspection and maintenance are unlikely to be met in high rise, multi-ownership buildings. Such buildings are far more difficult to inspect due to complications in terms of access to the façade and the increased area of wall. The facades also tend to be more complex in terms of geometry, penetrations and features such as windows and balconies.

If simple maintenance and inspection is not carried out, the specific conditions of the Agrément Certificate are not met, and therefore additional precautions should be taken to account for this. A drained cavity behind the insulation will add to the robustness of the wall and provide a drainage path out of the wall should any water pass the external render.

3.3.3 Interfaces

Interfaces remain a key concern and a potential area of weakness in terms of water penetration.

It is therefore recommended that interfaces are drained.

This is to ensure that any water passing the outer seal is not trapped within the wall where it may cause long term damage, an example is shown in *Figure 3.15*. This is discussed in greater detail in Chapter 5.

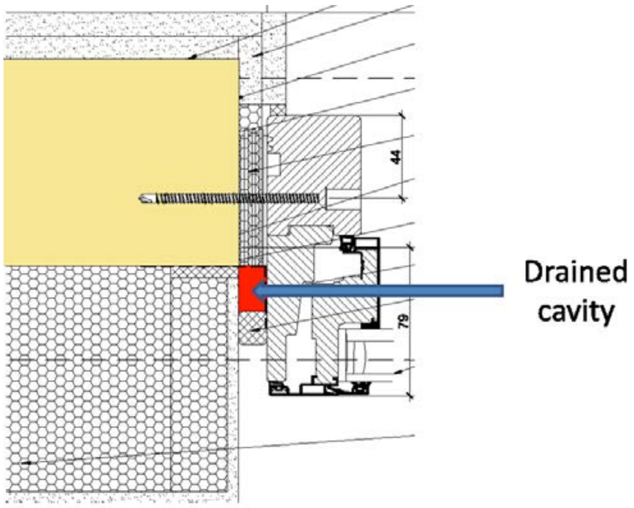


Figure 3.15 - Drained cavity at a window interface

4 COMPONENTS

This section looks at the components which make up a built-up wall. It is split into:

- components common to all built-up walls;
- rainscreen components;
- EWIS components.

4.1 Common elements of rainscreen/externally rendered insulation systems

Key components/elements of any built-up wall are:

- back wall;
- breather membranes, vapour control layers and air barriers;
- insulation;
- windows/doors.

4.1.1 Back wall

The back wall is the load bearing element of a built-up wall. It provides any fire resistance requirements, and will generally form the air barrier.

One of the keys to providing a successful built-up wall is to ensure that the back wall is sufficiently well constructed so that any water that passes the outer finish, be it a rainscreen or an EWIS, does not damage/get into the back wall. In order for this to be the case the back wall should be:

- designed appropriately, and with a knowledge of the external finish;
- constructed using suitable materials;
- well managed during construction;
- constructed with a high level of workmanship.

The back wall is critical to the performance of all rainscreen systems. If air movement through the back wall is too great, then the risk of water penetration past the rainscreen is increased. This is unlikely to be significant in walls that satisfy the air leakage requirements of the Building Regulations.

For both rainscreen and EWIS, air leakage through the back wall must also be minimised for reasons of energy loss through the façade.

The back wall can take various different forms and configurations. The back walls described in the following section can be categorised as being:

- solid,
- framed,
- panel systems.

4.1.1.1 Solid back walls

Rainscreen and EWIS were traditionally used in renovation projects and so solid back walls were often existing loadbearing masonry walls which were overclad. In more recent times solid back walls have been used in both refurbishment and in new build projects.

Solid walls may either be loadbearing or infill between floor slabs, *Figure 4.1*. Infill back wall require movement joints, and this movement must also be accommodated by the external cladding. Loadbearing back walls do not require horizontal movement joints, but vertical movement joints may be required for long walls.

Solid back walls are generally stiffer than framed walls. This results in a back wall which is more stable, which in turn means that there is a reduced risk of the failures (of both the back wall and the external finish) due to excessive movements of the wall.

Solid walls give more freedom in fixing locations for cladding.

The use of EWIS on solid back walls is described in further detail in Chapter 3.

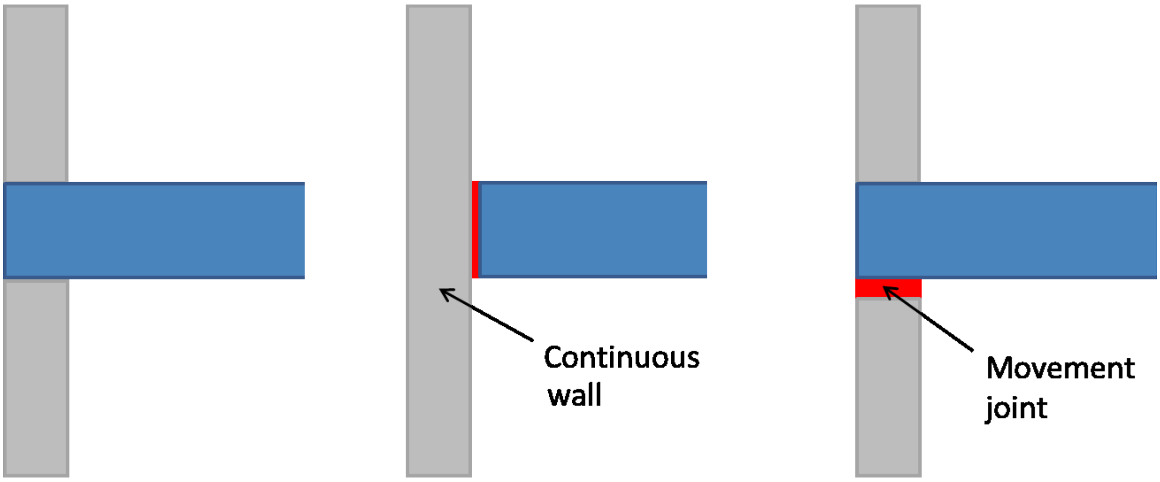


Figure 4.1 – Loading bearing back wall (left), self-supporting continuous back wall (middle), Infill back wall (right)

4.1.1.2 Framed back walls

Framed walls may be constructed from either timber or metal (typically steel) studs. Timber studs tend only to be used for low rise small scale buildings. A framed back wall consists of:

- frame/studs,
- sheathing boards (section 4.1.1.2.2),
- internal lining.

Thermal insulation (Section 4.1.3) and vapour control layers (Section 4.1.2.1) may also be included.

Framed back walls are required to support the cladding. Brackets supporting the rainscreen are normally fixed to the studs. Additional horizontal components ('top hats') may be required to transfer the loads back to the studs.

Framed walls (*Figure 4.2*) include:

- infill walling with dry lining, where the frame is fitting between floor slabs;
- continuous walling with dry lining, where framing members are fitting outside of the structural frame of the building, usually connected to the edge of floor slabs.

For infill walling, special tracks are usually fitted to the floor and soffit which then support the vertical members. This allows the back wall to be installed from inside the building.

Continuous walling oversails the edge of the primary structure and may be used where the design team wish to maximise the amount of internal floor area. Continuous walling may also be preferred where the cladding used cannot accommodate horizontal deflection joints at each level. Continuous walling is typically installed from outside of the building.

Further details on framed walls can be found in the SCI Technical Report: ED017, Design and installation of light steel external wall systems.

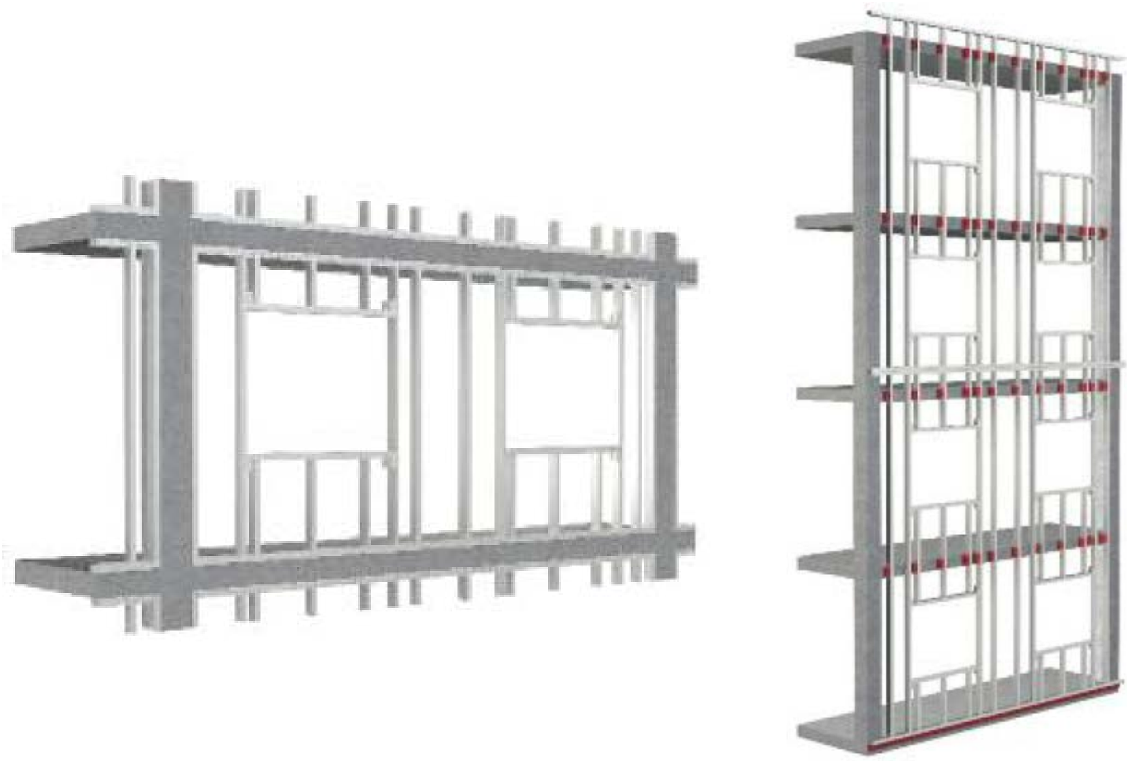


Figure 4.2 - Infill (left) and continuous (right) framing (© Metsec)

4.1.1.2.1 Brackets

A bracket may be classified as being:

- primary, or
- secondary.

Primary brackets connect framing members to the primary structure. Framing members predominantly take two forms; studs between floor slabs (infill wall) and framing members mounted on the edge of floor slabs (continuous wall) (*Figure 4.3*).

The primary brackets used depend on the framing system and the main structure of the building, and will consist of elements such as:

- angle brackets/cleats;
- channel sections;
- Z-shaped elements.

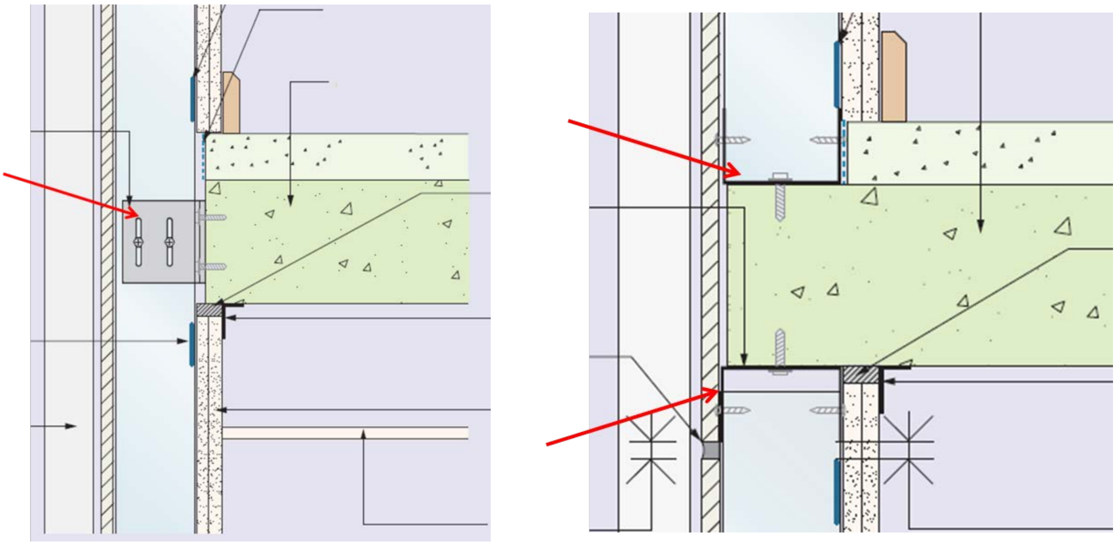


Figure 4.3 - Primary brackets connecting framing members to the structure (©Metsec)

Secondary brackets support panels or carrier rails from a back wall or framing member. The loads on a secondary bracket are smaller and issues such as thermal conductivity (thermal bridging) and corrosion resistance dominate.

Secondary brackets are discussed in further detail in Section 4.2.3.

4.1.1.2.2 Sheathing boards

Sheathing boards are generally used on the cold side of framed wall construction (*Figure 4.4*). The sheathing board provides a flat and stable surface onto which insulation/membranes for vapour control/water resistance can be fixed. They will also contribute to the racking strength of the wall.

The choice of board material and thickness will depend on a number of factors including:

- stud spacing;
- loading, due to:
  - external rails/panels;
- fixing requirements;
- condensation risk;
- conditions within the cavity.

It is recommended best practice to fix brackets through the sheathing boards in to the underlying studs (and noggins if provided). If the sheathing board is overlaid with an opaque membrane, then the setting out of the studs will need marking accurately on the membrane so that bracket fixings are aligned with the underlying studwork.

Some rainscreens however are designed such that the brackets supporting the cladding rails are fixed solely to the sheathing boards instead of fixing through to the studs behind. If this approach is taken the structural performance of the sheathing must be properly assessed, including appropriate safety factors etc. This will usually result in a thicker and heavier board than would be required if the brackets were fixed back into the studs. The ability of the bracket fixings to resist the required pull-out loads from the sheathing board should be tested on site at the outset of installation commencing, or beforehand; thereafter the same fixings should be used throughout or the pull-out tests repeated.

CWCT recommend that brackets are fixed directly into studs, or into horizontal rails that are in turn fixed to the studs.

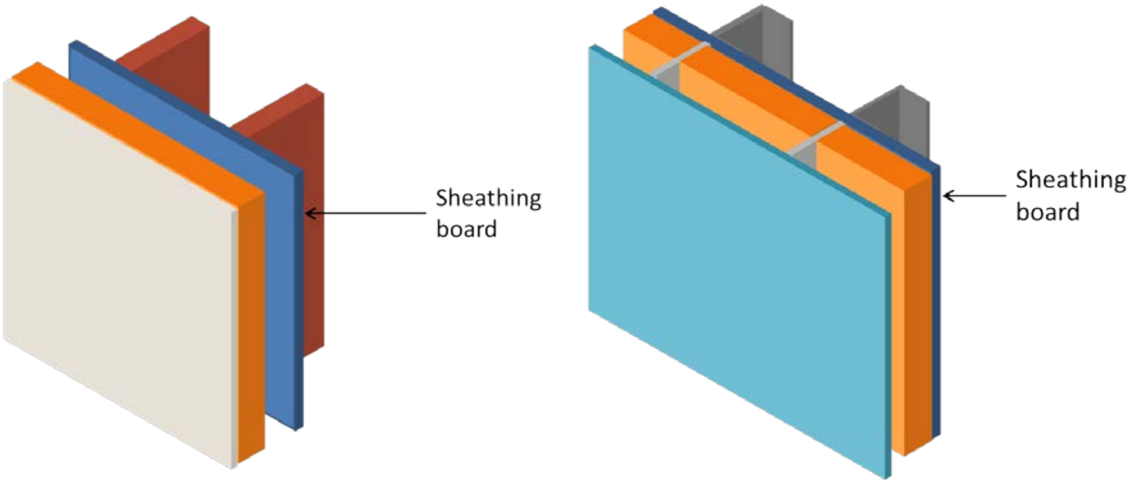


Figure 4.4 - Sheathing board in a framed wall, render system (right), rainscreen (left)

Water penetration may occur at fixings through the sheathing board as well as at unsealed gaps between adjacent boards (*Figure 4.5*).

In their Panel Guide, the Wood Panel Industries Federation (WPIF) recommends that wood-based sheathing fixed to the outside of framing, should have gaps of 3mm between adjacent panels to accommodate possible expansion due to moisture content increase. There may also be expansion due to thermal effects, although this is likely to be limited where there is insulation to the outside of the sheathing. This requirement presents a potential conflict with the need to keep any water out of the back wall.

A robust back wall specification will state that the gaps between adjacent sheathing boards are sealed. The aim of this sealing is to help ensure that any water reaching the back wall is stopped from penetrating further into the wall. How successful this is, is dependent upon how the boards are sealed, which may be by:

- tape;
- membrane strip and adhesive;
- sealant.

The most reliable way of sealing is to use strips of a membrane (such as EPDM) bonded to the sheathing boards with a compatible adhesive. This provides a long lasting solution however it is also the most expensive and may be seen as being over-specified.

Other solutions may not be as reliable. Taping the joints between boards is common however unlikely to be very effective. Although the tape should be fairly well protected it is not known how it will function long term, and therefore its performance cannot be guaranteed. The life will be reduced further if the tape is exposed to moisture.

Sealant may be used to seal between boards however this is also unlikely to provide a robust solution as typically the sealant is simply gunned between the boards. This is not only highly workmanship dependent but also impossible to ensure an adequate depth of sealant is applied to the joint. In addition, sealant applied in such a way does not offer any real movement accommodation (be it thermal, moisture or structural movement). Use of sealants such as silicone can also make the bonding of window membranes more difficult, and incompatibility can lead to weather ingress and air egress. Compatibility between all elements is essential for a robust whole wall solution.

Figure 4.5 - Fixing into sheathing causing water penetration, poor workmanship when sealing the boards (left), damage during fixing (right)

Depending on the build-up of the wall sealing, the sheathing boards may result in an increased risk of interstitial condensation at that position. This is because the sealed layer may act to trap moisture vapour migrating through the wall from the inside. Factors that will affect this include:

- internal and external psychrometric conditions:
- position of any vapour control layers;
- sheathing board material properties;
- wall build up;
- insulation position.

Ensuring that the dew point of the wall is to the cold-side of the sheathing will significantly reduce the risk of condensation causing problems. Condensation risk analysis will be discussed in greater detail in Chapter 6.

An alternative to sealing the sheathing boards is to incorporate a membrane into the construction (Section 4.1.2). The Wood Panel Industries Federation recommends that it is good practice to tape or gasket panel joints where there is no breather membrane.

Membranes are discussed in greater detail in Chapter 5.

Commonly used sheathing board materials include:

- cement particle board;
- calcium silicate board;
- oriented strand board;
- plywood,
- gypsum boards.

Further information may be found in the Wood Panel Industries Federation Panel Guide.

4.1.1.2.2.1 Cement particle board

Cement particle board (or cement bonded particle board, cement board, CPB) is made of a combination of cement and treated timber flakes/particles, which are compressed and heated to allow the cement to harden and form a board, *Figure 4.6*. Additional additives may be added to the mix to improve certain aspects of the performance. Cement particle board is the most commonly used sheathing board.

Boards are generally easy to work with, using general woodworking tools. Board thicknesses range from approximately 8mm to 40mm depending on the application.

The general properties of cement particle board are:

- high durability;
- high resistance to moisture;
- good fire performance (class 0, B-s1 d0 to EN 13501-1);
- high stiffness (depending on the thickness and the span between supports);
- good sound insulation.

In addition to its use as a sheathing board, cement particle board is also well suited to use as a backer board for render applications. This is due to its dimensional stability and impact resistance in addition to its moisture resistance.

Cement particle boards in an untreated state are weather resistant and will not degrade with permanent exposure, even if subjected to freeze/thaw conditions. However, in general, a surface treatment is recommended for external applications (ie as cladding rather than sheathing) which improves its moisture resistance.

Figure 4.6 - Cement particle board

4.1.1.2.2.2 Calcium silicate board

Calcium silicate together with various fibres for reinforcement are autoclaved to produce a high quality board material (*Figure 4.7*). As with cement particle board calcium silicate boards are:

- dimensionally stable;
- non-combustible (class 0, A1 to EN 13501-1);
- moisture resistant;
- easy to use (cut with woodworking tools).

In addition, they are more flexible than other sheathing boards making them particularly suited to curved facades.

The main use for calcium silicate boards is as a render base board, however they may also be used as sheathing in framed walls.

Figure 4.7 - Calcium silicate board

4.1.1.2.2.3 Oriented strand board (OSB)

OSB is composed of thin rectangular shaped wood strands arranged in layers at right angles to each other (*Figure 4.8*). The layers are laid into mats and bonded with an adhesive to form a panel. Panels may be treated with a sealant on panel edges to protect against moisture penetration during shipment and erection.

OSB panels have no internal gaps or voids, and are water-resistant, although they do require additional membranes to achieve impermeability to water and are not recommended for exterior use. The surface may also have a wax coating to improve water resistance of the product.

OSB is hygroscopic and its dimensions change in response to a change in humidity. Boards must therefore be conditioned to bring it into equilibrium with its environment before it is fixed. This is usually achieved by loose stacking of the panels in the room where they will be used prior to fixing them. It is recommended that a small gap (3 mm) be left between panels to allow for any expansion due to increased levels of moisture. Boards used for sheathing are available in a range of thicknesses from approximately 7.5 mm to greater than 20 mm.

Different grades of OSB are available, depending on their intended use. BS EN 300: 2006 –*Oriented Strand Boards (OSB) - Definitions, classification and specifications* is used when specifying OSB. Four grades of OSB are defined in BS EN 300 in terms of their mechanical performance and relative resistance to moisture. These are:

- OSB/1 - General purpose boards and boards for interior fitments (including furniture) for use in dry conditions;
- OSB/2 - Load-bearing boards for use in dry conditions;
- OSB/3 - Load-bearing boards for use in humid conditions;
- OSB/4 - Heavy-duty load-bearing boards for use in humid conditions.

Physical wetting of all grades of OSB should be avoided. When wet, OSB will increase appreciably in thickness.

For use as sheathing boards, OSB/3 or OSB/4 is recommended.

Figure 4.8 - Orientated strand board

4.1.1.2.2.4 Plywood

Plywood is made of thin sheets of wood veneer bonded together (*Figure 4.9*). Adjacent plies have their grain at right angles to each other to improve the properties of the board in terms of dimensional stability, strength and resistance to splitting. Various coatings or treatments can be applied to plywood to enhance its physical characteristics and performance, including durability, fire resistance, abrasion resistance etc.

Various timber species can be used for making the plies, from softwoods such as Douglas fir or pine to hardwoods such as birch, and also tropical hardwoods, with the end use determining the materials used. Softwood is generally used for sheathing purposes.

There are several different types of plywood available for use in different applications. They are:

- interior plywood;

- exterior plywood;
- marine plywood;
- structural plywood.

The main differences between the types are the species of wood that are used and the glues used to bond them together.

Interior plywood uses an adhesive which is not water resistant and therefore must only be used internally where moisture levels are low. Typical uses include warm roofs, intermediate floors and internal walls.

The glues used in **Exterior grade plywood** are much more resistant to moisture than interior plywood. End uses include cold roofs, ground floors and timber frame external walls.

Marine plywood may be used when moisture resistance is a priority. The adhesive used is similar to that used for exterior ply, however the boards are manufactured to a higher quality with few defects so that it performs longer in humid and wet conditions and resists delaminating and fungal attack

When the appearance of the face is of lesser concern than the strength and stability of the material, **structural plywood** may be used. The adhesive used is designed for extra strength to avoid separating of the layers. Structural plywood is commonly used in concrete forms on construction sites.

BS EN 636:2012 – *Plywood – Specifications* refers to EN 636-1, EN 636-2 and EN 636-3 when specifying plywood to be used in dry, humid and exterior conditions respectively, however all three Standards have now been withdrawn.

Boards specified according to EN 636-1 are suitable for use when the humidity of the surrounding air only exceeds 65 per cent (at 20°C) for a few weeks per year.

Boards specified according to EN 636-2 are suitable for use when the humidity of the surrounding air only exceeds 85 per cent (at 20°C) for a few weeks per year. It notes that this plywood is appropriate for protected external applications (e.g. behind cladding or under roof coverings), but is also capable of resisting weather exposure for short periods (e.g. when exposed during the construction). It is also suitable for interior situations where the service moisture condition is raised above humidity of dry conditions.

Boards specified to EN 636-3 are capable of withstanding exposure to weathering conditions and liquid water, or water vapour in a damp but ventilated location.

Plywood may also be graded on the condition of the front and back veneers. This would be of obvious importance if the boards were visible, but may also affect the strength of the material.

For applications such as sheathing, used in situations that are generally dry with only occasional wetting during the construction process or in service, TRADA recommend exterior grade plywood to EN 636-2.

Figure 4.9 - Plywood

4.1.1.2.2.5 Gypsum boards

Gypsum sheathing boards comprise a highly compressed core of gypsum and different fibres, such as cellulose or glass, typically with a treated paper facing. Other facing materials are available (eg glass fibre mat) in order to give enhanced performance/resistance to moisture. They have good fire resistance (Class 0, A2 to EN 13501-1)

Gypsum boards moisture resistant however should not be exposed to long-term wetting. They are dimensionally stable so can be installed without a gap between adjacent boards. They provide good resistance to air movement, however this will depend on the sealing between boards.

Boards are lightweight and easy to handle. They can be cut easily using the 'score and snap' method, and trimmed with a saw if required.

BS EN 520:2004 covers definitions, requirements and test methods for gypsum boards.

4.1.1.3 Structural insulated panels (SIPs)

SIPs are a modern method of timber frame construction (*Figure 4.10*). They are a composite panel comprising a sandwich of orientated strand board (OSB, see Section 4.1.1.2.2.3) and an insulation core typically of polyurethane (PUR) or polyisocyanurate (PIR) foam (see Section 4.1.3.4). They are mainly used for low-raise buildings (up to two storeys), but may be used for higher buildings if appropriately engineered. They can also be used non-structurally – i.e. as an infill wall.

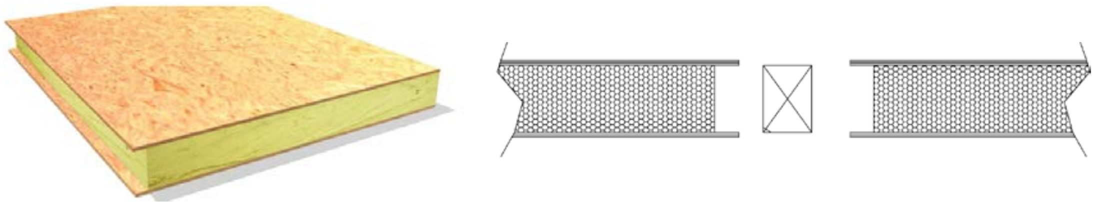


Figure 4.10 - Structurally insulated panel (left), reinforced junction (right)

SIPs are fabricated offsite and therefore erection onsite is very rapid. The panels are lightweight, highly insulated and airtight. They are available in different thicknesses to suit different U-value requirements.

Depending on the structural requirements the junction between the SIPs may have to be reinforced with a timber or steel post (*Figure 4.10 right*). In such cases the reduction in thermal performance due to the thermal bridge caused by the structural element should be accounted for.

SIPs may be used as the back wall for a rainscreen system. Due to their insulated nature, SIPs are not used with EWIS as described in Chapter 3. Instead the render is applied to a carrier board (such as cement-bonded particle board – see Section 4.1.1.2.2.1) with a cavity between the board and the SIP.

The rainscreen may be attached in the normal way via brackets and rails back to the SIP. There may be limits to loads that can be accommodated in this way due to the pull out strength of the fixings into the face of the SIP. Alternatively, the rainscreen may be attached via continuous steel top hat sections or timber battens fixed to the SIP.

The outer face of the SIP should be protected from wetting. This is crucial as there is unlikely to be any insulation protecting the outer face from any water penetrating past the rainscreen/external render, and therefore any exposure will be more severe. This will usually take the form of a breather membrane. A vapour control layer used in this position is likely to result in a condensation issue due to the position of the insulation in the wall (see
Section 4.1.2).

4.1.1.4 Composite insulated panels

Composite insulated panels may be used in a similar way to the SIPs described above. Composite insulation panels consist of an insulation core (typically PIR or PUR, see Section 4.1.3.4) with an inner and outer metal skin.

Various fixing arrangements are possible including using the panels as a continuous back wall. This can be achieved by means of metal angles/sections attached to the back of the panel which can then sit on the slab edge.

The outer skin is more durable than that of a SIP so a breather membrane may not be required, providing the joints in the back wall are adequately detailed to be watertight.

4.1.2 Vapour control layers and breather membranes

The control of moisture within a built-up wall is key to the long term performance. Sources of moisture include water vapour from the internal or external environment as well as liquid water in the form of rain. Control of moisture within the wall may be achieved with the use of breather membranes and/or vapour control layers.

Vapour control layers (VCL)
A vapour control layer:

- **restricts** the transfer of moisture vapour;
- **restricts** the transfer of liquid water;
- a continuous VCL will act as an **air barrier**;
- should be placed to the **warm side** of the dew point of the wall.

Breather membranes
A breather membrane:

- **allows** the transfer of moisture vapour;
- **restricts** the transfer of liquid water;
- **may** act as an **air barrier**;
- usually positioned to the **cold side** of the dew point of the wall.

VAPOUR CONTROL LAYERS AND BREATHER MEMBRANES ARE NOT INTERCHANGEABLE.

4.1.2.1 Vapour control layers

Vapour control layers are provided where required to control the migration of water vapour into elements of construction vulnerable to condensation. A wall has to be constructed to limit the moisture content within the wall to acceptable levels. No condensation should be allowed to form or collect in any voids or interstices where such water may have a deleterious effect on the materials or on the wall's performance.

The appropriate use of a vapour control layer can reduce the risk of interstitial condensation. However, a wrongly positioned or inadequate vapour control layer may serve to trap water vapour within the wall.

A condensation risk analysis may show that no vapour control layer is required. However, designers may choose to incorporate an effective vapour control layer rather than carry out a full condensation risk analysis. The provision of an effective vapour control layer also adds to the robustness of the wall. It will limit moisture content throughout the wall and help reduce condensation at any cold bridges remaining within the design or introduced by shortcomings in workmanship.

The need for a vapour control layer will depend on the:

- vapour permeability of each layer;
- temperatures within the wall;

- position of the dew point;
- internal and external moisture levels;
- effectiveness of any ventilation of the cavities within the wall.

Vapour control layers may comprise metal sheets, metal foils, plastics, polymeric sealants and liquid applied coatings. The effectiveness of any vapour control layer will depend on the material used and its installation.

Vapour transmission of a membrane is assessed in accordance with BS EN 1931: 2000 - *Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of water vapour transmission properties*. Following the test procedure, a manufacturer's declared value is given.

Where a vapour control layer is used without calculating the wall temperatures it should be placed to limit water vapour migrating from the warm parts of the wall to the cooler parts of the wall. Typically, for UK-like climates where moisture levels are higher inside than out, vapour control layers are placed as shown by the arrows in *Figure 4.11*:

- at the warm side of the dominant insulating layer:
  - between the insulation and (uninsulated) back wall in a ventilated rainscreen wall, where the insulation is absorbent;
- at, or near, the inner face of the wall:
  - a dense plaster finish to a blockwork wall,
  - foil backed plasterboard as a dry-lining behind a blockwork wall.

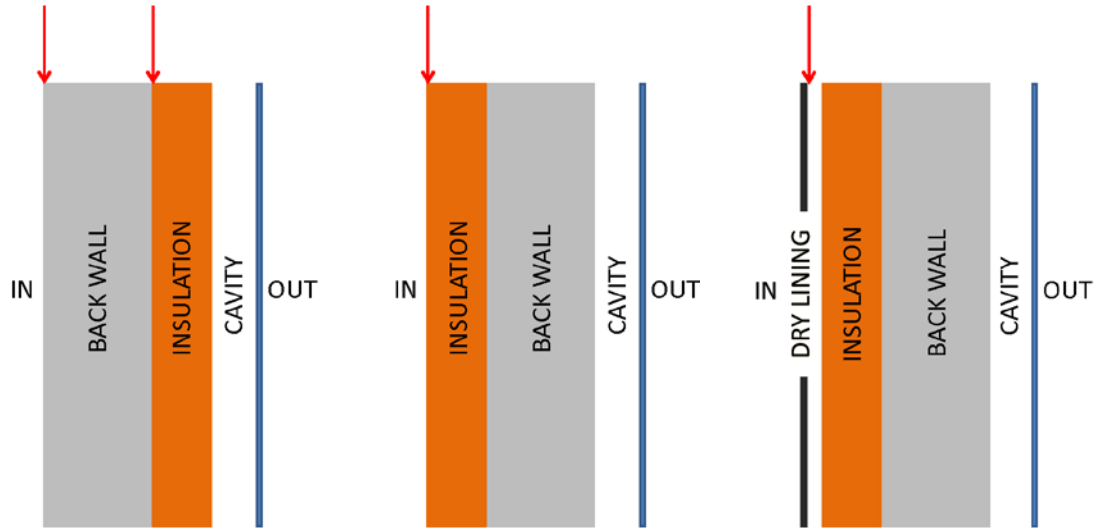


Figure 4.11 - Typical vapour control layer positions

Installation of a vapour control layer may require the material to be lapped or pierced by fixings. The materials may also become pierced as a result of damage during construction (*Figure 4.12*). The design should have due regard for the means of installation and the susceptibility to condensation related problems. Where required, taping or sealing of joints should be specified and precautions taken to ensure that any discontinuity or piercing of the layer by essential fixings does not compromise the performance. Damage occurring during the installation of the vapour control layer should be repaired utilising the same VCL membrane and type of sealant.

Figure 4.12- Poorly installed/damaged vapour control layer

In the detailing of buildings, it is commonplace for significant discontinuities in vapour control layers to occur at the interfaces of adjacent elements, such as window reveals. It is therefore essential that interfaces between different elements and subcontract packages are duly considered and addressed during the design and detailing stages.

A continuous vapour control layer will also act as an air barrier, however to resist air the membrane will require greater support. .

There is no standard test to obtain the air tightness of a membrane.

4.1.2.2 Breather membranes

Breather membranes are sheet or liquid applied materials that contain many very small holes or pores. These are large enough to allow water vapour to pass but resist the passage of liquid water.

The function of breather membranes is to provide a barrier against water penetration from the outside whilst allowing migration of water vapour through the membrane from inside the building. Whilst being typically associated with rainscreens, their use is not always well understood and they are not always required.

The watertightness of a membrane is assessed in accordance with BS EN 1928: 2000 - *Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of watertightness*. The result of the test is pass or fail.

Vapour transmission of a membrane is assessed in accordance with BS EN 1931: 2000 - *Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of water vapour transmission properties*. Following the test procedure, a manufacturer's declared value is given.

CWCT Technical Note 33 - *Breather membranes and vapour control layers in walls*, recommends that breather membranes marketed as products should have a vapour resistance less than 0.6 $MNsg^{-1}$. This is to ensure that the vapour resistance is always much less than any other layers in the wall.

BS 5250: 2011 – *Code of practice for control of condensation in buildings* defines a breather membrane as one with water vapour resistance greater than 0.25 MNs/g and less than 0.6 MNs/g.

Typically, a breather membrane would be used on the outer face of insulation within the rainscreen cavity to protect it from any water passing the outer panels, however in practical terms this is not ideal. In order for the breather membrane to effectively protect the insulation from wetting it is important that it is continuous across the surface. Therefore, penetrations due to rainscreen brackets should be fully sealed which is often difficult to achieve.

An alternative position is on the outside face of the sheathing board, if the dew point is in-board of the sheathing board. This is easier to install as it is against a flat surface and penetrations due to fixings are essentially sealed by the bracket which is attached. Depending on the type of sheathing boards used and the sealing between adjacent boards a breather membrane in this position may not be necessary but may still be specified.

A breather membrane should be provided unless it can be established that:

- any insulation in the cavity is resistant to wetting, for instance some closed cell foams and mineral fibre insulation with water repellent additives;
- no water reaches the backing wall, either directly or by migration through the insulation.

When a non-absorbent insulation is used (such as rigid foam), a breather membrane may not be required to protect the insulation, however one may still be used as an additional line of defence against water penetration.

The breather membrane should be placed in either of the positions shown by the arrows in *Figure 4.13*:

- on the cold side of any insulation that is intolerant of water,
- on the cavity face of the back wall if any insulation is resistant to wetting:
    - o a vapour control layer may also be used in this location where the back wall is not sufficiently insulated for the dew point to be inboard of the vapour control layer;
- on the cavity face of the back wall if no insulation is present in the cavity.

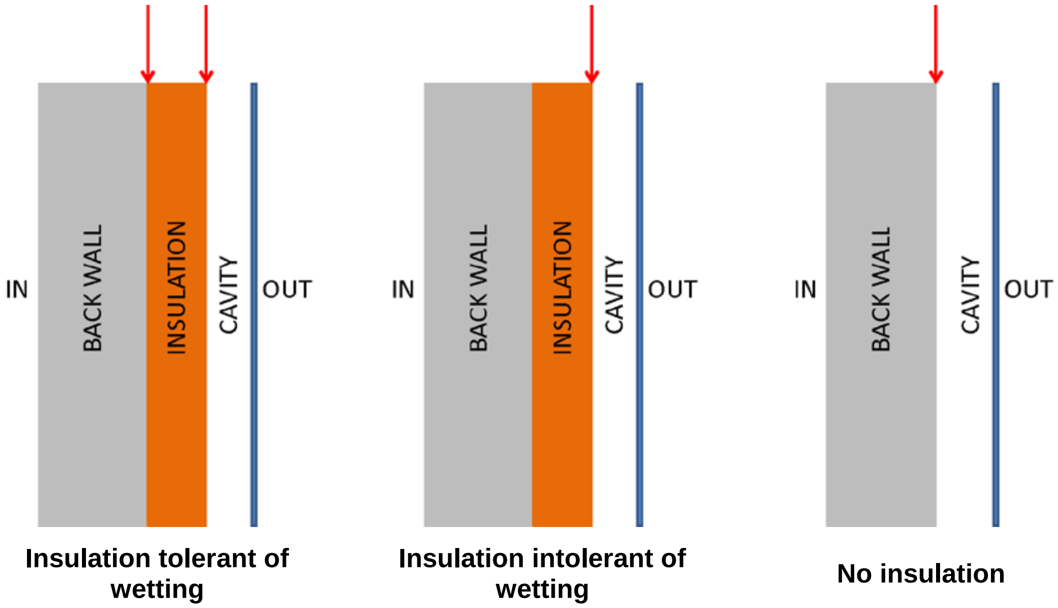


Figure 4.13 - Typical breather membrane positions

If a breather membrane is to be used it is vital that it is specified and installed correctly as one which is unsuitable (for example insufficiently vapour permeable) or poorly installed may trap vapour migrating out through the wall or water in the wall which has found its way there from the outside. Condensation risk analysis will be discussed in greater detail in Section 6.8.

Figure 4.14 - Breather membrane behind a timber rainscreen

Depending on the construction of the outer rainscreen, the breather membrane may be visible through gaps in between panels, an example is shown in *Figure 4.14*. Where the membrane is exposed its resistance to degradation due to UV light must be considered. UV resistant membranes are available. Membranes are also available in a range of colours and the required colour should be specified if it is deemed important.

Likewise, a breather membrane may be used so that the insulation in the cavity is not visible.

The fire performance of any membrane exposed to a cavity should also be considered. Fire is discussed further in Section 6.6.

If a breather membrane is intended to be the principal water barrier there is a need to consider factors such as:

- how to seal around penetrations;
- can the material used act as an air barrier, or is a separate air barrier required;
- how the slab edge deflections are accommodated:
- how the membrane will be secured to resist cyclic wind loading;
- how the membrane will be secured around steel edge beams.

The position of vapour control layers and breather membranes in discussed in greater detail in Chapter 5.

4.1.2.3 'Intelligent' membranes

'Intelligent' membranes are membranes which have declared vapour resistance/permeability which vary dependent upon the heat flow direction through the built-up wall and the prevailing relative humidity. Also known as 'climate' membranes their diffusion resistance reduces with high humidity and temperature, e.g. during summer months and increases with lower humidifies and temperatures associated with winter months.

Although the variable diffusion resistance gives these membranes the properties of both a vapour control layer and a breather membrane, dependent upon the prevailing humidity, they should ideally be positioned within a built-up wall construction as would a vapour control layer as described in Section 4.1.2.1 above.

When carrying out a condensation risk analysis the variable diffusion resistance properties of these membranes can only be fully realised when using a dynamic calculation method. A fixed diffusion resistance value can usually be provided by the membrane manufacture if a simplified steady-state calculation method is used. Condensation risk analysis is discussed in greater detail in Section 6.8.3.

'Intelligent' membranes when fully sealed can also act as an air barrier. They are also suitable for sealing interfaces such as with window and door frames especially where the sealing membrane may need to bridge the position of the dew point of the interface detail. Interfaces are discussed in greater detail in Chapter 5.

4.1.3 Insulation

The choice of insulation material used depends on a number of factors including:

- the required thermal performance;
- the thickness of insulation allowed/thickness of cavity/overall wall;
- the position in the wall build-up;
- the type/condition of the substrate;
- fire performance/regulations;
- compatibility with render materials;
- acoustic performance/requirements.

There are four main insulation types used in rainscreens/EWIS:

- expanded polystyrene (EPS);
- mineral fibre;
- phenolic foam;
- polyurethane (PUR) and polyisocyanurate (PIR).

EPS and mineral fibre are probably the most commonly used insulation materials for EWIS in the UK. Phenolic foam and mineral fibre are most commonly used in rainscreen systems.

4.1.3.1 Expanded polystyrene (EPS)

EPS is very lightweight and easy to work with, and once fitted can be shaped/planed, for example prior to the application of an external render. EPS insulation should be manufactured in accordance BS EN 13163 and the essential characteristics declared.

EPS provides good thermal performance (typical thermal conductivities of between 0.035 and 0.040 W/mK), and has an excellent BREAAM rating of A+.

The main disadvantage of using EPS insulation is its fire performance. When exposed to high temperatures it melts/combusts and therefore offers no integrity in the event of a fire, and can form voids and burning droplets allowing fire spread. .

UK Building Regulations set stringent fire safety requirements for high rise projects (defined as having an occupied floor above 18m in height). Therefore, there are limitations to the use EPS insulation in high rise buildings. This is discussed in more detail in Chapter 6.

Figure 4.15 - Expanded polystyrene insulation © WBS-LTD (left) Knauf (right)

EPS boards are typically available in sizes up to 1000 x 500mm (0.5m^2) and in thicknesses up to 300mm. Boards can either be straight edged or alternatively tongue-and-groove details are available to ensure that gaps between adjacent boards are minimised, *Figure 4.15*.

EPS boards can be adhesively or mechanically fixed to the substrate.

4.1.3.2 Mineral wool insulation

Mineral wool insulation is manufactured from filaments spun from molten rock, slag or glass with a binder and often an oil to reduce dusting. Mineral wool insulation should be manufactured in accordance BS EN 13162 and the essential characteristics declared.

Mineral wool insulation is available in numerous formats such as boards, slabs, batts, rolls and mats and varying densities. For rainscreen and EWIS the main formats used are batts, boards and slabs. A batt is a rectangular piece of insulation mat typically 1 m to 3 m in length supplied folded or flat whilst boards and slabs are rigid or semi-rigid in a rectangular shape with boards being thinner than slabs. The term batt will be used in this section.

Typical thermal conductivities range from 0.031 – 0.044 W/mK, with the value depending on the density of the insulation. Rock mineral wool will have a typical density range between 23 – 200 kg/m^3 whilst glass mineral wool will have a typical density range between 10 – 80 kg/m^3. For the more commonly used rock mineral wool there is an optimum density for thermal insulation at approximately 50 kg/m^3 with the conductivity increasing at both lower and higher densities, however the change is relatively small over the range from 30 to 150 kg/m^3.

Mineral wool insulation provides a similar thermal performance to that of EPS, and has an excellent/very good BREAAM rating of A+/A depending on the density. The acoustic absorption of mineral wool is also very good, making it a good choice where external sound levels are high or where a particularly quiet internal environment is specified. The insulation has excellent 'breathability', allowing the movement of water vapour through the wall, which can be beneficial in the reduction of interstitial condensation risk. If a high vapour permeability is important it is crucial that the other elements of the built-up wall (adhesives, renders etc.) are compatible with such requirements.

Perhaps the greatest advantage that mineral wool insulation has over other insulation materials is its fire performance. Mineral wool is non-combustible (typically class A1 under BS EN 13501-1 – *Fire classification of construction products and building elements. Classification using test data from reaction to fire tests,* although will depend upon the amount of binder used) so does not directly contribute to the spread of fire. Mineral wool from rock is often used as a fire barrier in rainscreens/EWIS which use combustible insulation.

Although mineral wool batts can be treated to be water repellent, issues of water absorption may occur if it is subject to prolonged contact with water, for example due to water ingress past the outer face of the wall/at an interface, or due to moisture trapped in the wall caused by interstitial condensation.

Mineral wool insulation batts are available in a lamella version (with the fibres perpendicular to the face) and a non-lamella version (with the fibres parallel to the face).

The lamella version is available in sizes up to 1200 x 200mm (0.24m^2), which is smaller than for other forms of insulation products, making them more time consuming to install. They have the advantage of being more flexible than other formats making them ideal for walls which are slightly curved. They can be shaped/rasped once installed to give a flat surface. Thicknesses of up to 300mm are available and they can be adhesively fixed to the substrate. Lamella may give better support to the render due to fibre orientation when used for EWIS. Because of this lamella mineral wool is more likely to be used in an EWIS than a rainscreen, where it does not offer any advantages over non-lamella slabs.

Non-lamella mineral wool batts are available in larger sizes (up to 1200 x 600mm, 0.72m^2) and thicknesses typically up to 180mm which is thinner than other insulation boards; however, the thermal conductivity is slightly lower than the lamella version. Mechanical fixings are required even when an adhesive is used. This is because the fibres of the batt run parallel to the surface meaning there is a risk of delamination which could lead to a serious failure if mechanical fixings are not used. Due to the orientation of the fibres, they are more difficult to shape once installed, which may be problematic for EWIS application.

Non-lamella slabs are available in dual densities. Dual density batts have the advantage of a low density inner layer which is quite soft and will therefore deform to accommodate irregularities in the back wall, and a higher density, firmer outer layer that allows for secure fixing and application of render.

Figure 4.16 - Mineral wool insulation © Rockwool

4.1.3.3 Phenolic foam insulation

Phenolic boards are foam plastic insulation with a foil facing, for use in rainscreen walls. The foil facing improves fire performance and may improve the thermal performance by providing a low emissivity surface although this may become ineffective when it becomes dirty. Phenolic foam insulation should be manufactured in accordance BS EN 13166 and the essential characteristics declared.

The thermal conductivity of phenolic boards is amongst the lowest of all commonly available insulation materials, with typical values between 0.020 and 0.025 W/mK. This means that thinner layers of insulation may be used to meet the required U-value.

The fire performance of foil-faced phenolic foam is good. It combines zero or very low flame spread with negligible smoke emission and a very low level of toxic gas emission. Phenolic foam is a thermoset material therefore will not run, melt or drip when it comes into contact with a fire source. It is rated as class 0 in the UK and class B-s1-d0 under BS EN 13501-1. However it is combustible and its use is restricted in high rise buildings. This is discussed in greater detail in Chapter 6.

Phenolic insulation boards (*Figure 4.17*) are the most expensive of the commonly used insulation materials, however this additional cost needs to be weighed up against the space savings from having a thinner overall wall thickness.

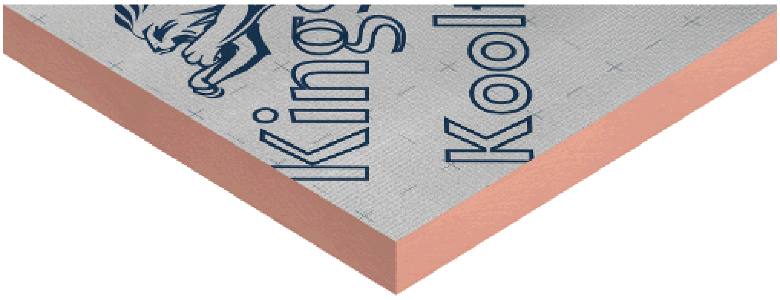


Figure 4.17 - Phenolic foam insulation © Kingspan

Phenolic insulation boards are available which have a Green Guide rating of A+.

4.1.3.4 Polyurethane (PUR) and polyisocyanurate (PIR) insulation

PUR and PIR are rigid insulation boards which may be used in rainscreen cladding. PUR is produced by blowing a gas into urethane resin to give an insulating foam. The gas used gradually escapes over time so for this reason, and to stabilise the foam into boards, they are usually faced with aluminium foil. PIR is similar to PUR, however it is made using a different polymer to produce a board which is stiffer, able to withstand higher temperatures and gives off less dense smoke in the event of a fire. PUR/PIR insulation should be manufactured in accordance BS EN 13165 and the essential characteristics declared.

PUR/PIR insulation boards (*Figure 4.18*) have a very low thermal conductivity, typically around 0.025 W/mK.

The insulation material itself is combustible, however foil facings on the boards may reduce the surface spread of flame. Information from board manufacturers should be sought on the exact properties of the materials. As with phenolic insulation, its use in high rise buildings is restricted.

Perhaps the most common use of PUR/PIR insulation is in composite panels (sandwich panels), where the insulation is bound by two metal facings (usually steel or aluminium) and in structurally insulated panels (SIPs), where the insulation is bound by two layers of orientated strand board (OSB).

Figure 4.18 - PUR/PIR insulation boards © Celotex

PIR insulation boards are available with a Green Guide rating of A or A+ depending on the configuration.

4.1.3.5 Water absorption of insulation materials

Most commonly used insulation products will absorb water unless measures are taken to limit this. The amount of water reaching the surface of the insulation in a rainscreen wall will depend on the cavity depth, type and size of joints between the rainscreen panels, and the external conditions (wind and rain).

Standard tests are used to determine short term (BS EN 1609) and long term (BS EN 12087) water absorption, with different absorption limits given for different materials.

Water absorption is perhaps best understood with mineral wool insulation, where in its natural state, it readily absorbs water. Additives are commonly added to the fibres in order to increase the water repellent nature of the surface, thus making it suitable for use in a rainscreen.

Foam plastic insulation materials as a phenolic or polyurethane are commonly referred to as 'closed cell' materials, and as such are assumed not to absorb water. This is not the case. Phenolic foam manufactured to BS EN 13166 or polyurethane and polyisocyanurate foams to BS EN 13165 need comprise less than 10 per cent of open cells to satisfy their European product standards. The DoPs often only declare a pass/fail for closed cell content.

Consequently to avoid water absorption in built up wall constructions partially open cell plastic foam insulation materials have some facing of plasticised metal foil bonded to the insulation core. The taping of joints between boards, around penetrations and at exposed edges is required. The physical and contractual responsibility for taping requires clarification if these products are considered a line of defence against water penetration, and to ensure that their thermal conductivity or service life is not diminished by wetting.

For all insulation materials an appropriate specified and installed breather membrane may be used to protect the insulation, Section 4.1.2.2.

4.1.3.6 Taping joints in the outer face between insulation boards

Agrément certificates for many foam plastic insulation boards state that the joints between boards should be taped as discussed above.

In addition to protecting the cut edges of the insulation, taping of the joint between insulation boards may influence:

- resistance to water penetration;
- vapour control;
- thermal performance.

In order to effectively protect the insulation and to create a water barrier (see Chapter 5), the taped joints must be perfect, and remain so for the lifetime of the insulation. This is highly workmanship dependant, particularly around fixings and bracket penetrations, *Figure 4.19*.

Figure 4.19 – Foil face insulation boards, taped joints and bracket penetrations

It should be recognised that some taped joints may fail. Where this occurs water may find its way past the tape and into the insulation, where it may be absorbed or track through the joints between the boards. There is the risk that the taped joints will now prevent this water getting back out of the insulation layer.

Taping the joints between boards at the outer face may also influence the risk of condensation forming. The vapour resistance of foil-faced insulation boards is much greater than insulation materials such as mineral wool (typical values are usually in excess of 50 MNs/g, compared to around 1 MNs/g for mineral wool). As such a continuous layer of foil-faced insulation boards will be quite resistant to the passage of water vapour, with the gaps between the boards providing the main path through which any water vapour passing through the wall will take. Taping the joint between the boards may create an inadvertent vapour control layer and trap this moisture vapour. This is in a cold area of the wall so is likely to condense. Breathable tapes are available which should avoid this problem. Compatibility between the tape and the insulation board should be confirmed with the manufacturers. A condensation analysis should be carried out to assess the risk of condensation forming, Section 6.8.3.

Taping the joints between the boards will reduce thermal bridging and air leakage/bypass, which would be detrimental to the thermal performance. This effect may be reduced or eliminated if the boards are fitted in such a way to ensure close butting joints. This is highly reliant on good workmanship, particularly around brackets and other penetrations.

4.1.4 Fixings

Insulation may be fixed back to the substrate (masonry if solid wall, sheathing board in a framed wall) by the following means:

- mechanical only:
  - rails,
  - screws,
  - proprietary fixings;
- adhesive only;
- adhesive and mechanical.

There are a number of factors which influence the choice of fixing method including:

- insulation material and thickness;
- substrate;
- substrate condition;
- cavity requirements;
- fire performance/Regulations;
- height of the building;
- ease of installation.

4.1.4.1 Mechanical fixings

Mechanical fixings are the traditional way of attaching the insulation to the back wall, and are used extensively despite advances in adhesive technology.

Mechanical fixings are the default choice for the insulation within the cavity of a rainscreen wall, *Figure 4.20*. This is because there will often be a membrane (VCL or breather membrane) on the cavity face of the back wall to protect the wall from any water passing the rainscreen and insulation. The membrane is usually simply stapled to the back wall and therefore is not a suitable surface on which to bond the insulation.

For an EWIS adhesive is more common but mechanical fixings are required where:

- the surface of the substrate or the insulation material is not suitable for adhesive;
- a cavity is required behind the insulation.

A mechanical fixing may also be specified due to perceived additional security/robustness that it provides, despite appropriate adhesive technology working just as well.

For rainscreen systems where mechanical fixings are used, the CWCT *Standard for systemised building envelopes* states that a minimum of one extra non-combustible fixing per square metre or per batten of insulation, whichever is the lesser, shall be provided to prevent detachment of the insulation in the event of a fire.

For EWIS where mechanical fixings are used, BRE Guide BR 135 – *Fire performance of external thermal insulation for walls of multistorey buildings* requires no fewer than one stainless steel fixing (in addition to plastic fixings) per square metre of insulation. This is to prevent excessive fire spread and system collapse.

Fire is discussed in greater detail in Section 6.6.

Figure 4.20 – Typical insulation fixings in a rainscreen system

There can be problems with mechanically fixed rails as shown in *Figure 4.21*, with some manufacturers now producing proprietary fixings so that they may be avoided. The main issue of such systems is that they can be installed incorrectly, in particular with regard to the number and type of fixings that are used. Once the insulation is in place the rail cannot be inspected prior to the application of the external render. There has been at least one instance of the insulation/render falling from the building during high winds, and on investigation it was discovered that only half the correct number of fixings had been used. Therefore, it is vital that appropriate QA and checking is in place during construction (see Chapter 2).

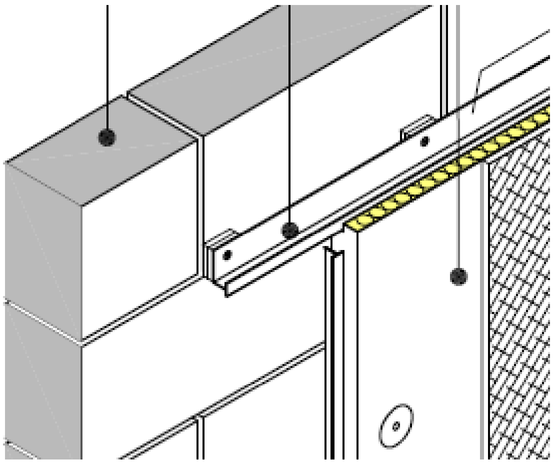


Figure 4.21 - Mechanical rail fixed system © STO

The proprietary fixings discussed in Section 3.3.2 have the advantage that they can be inspected before the render is applied so it can be checked that the correct number have been used. They may also have a higher pull out strength than traditional mechanical fixings.

4.1.4.2 Adhesive fixing

Adhesive fixing of the insulation to the back wall may be used in an EWIS.

In order for an adhesive to be used the surface on to which the insulation is to be bonded must be sound. Surfaces may include boards or masonry, in addition to paint and existing render in a refurbishment project. Depending upon the condition of the surface and the materials involved a surface primer or other preparation may be required.

In addition to some surfaces being incompatible, certain insulation materials are also not suitable for adhesive fixing (non-lamella mineral wool for example which may delaminate). The advice of manufacturers should always be sought to ensure an appropriate solution is used.

4.1.4.3 Adhesive and mechanical fixing

Such systems generally rely on the adhesive fixing alone, with the mechanical fixing providing back up. Adhesives and mechanical fixings may be used together for a number of reasons:

- required for certain types of insulation (for example non-lamella mineral wool);
- the mechanical fixings may be used to hold the insulation boards in place while the adhesive cures – after that they are essentially redundant;
- the adhesive may act as a smoothing coat with the mechanical fixing required to assist in holding the insulation in place.

Such fixing configurations may be used with an EWIS.

4.1.5 Windows

Windows are a key component in most built-up walls, allowing light into the building and affording views out for the occupants inside.

The choice of window system will depend on factors such as:

- budget;
- appearance;
- performance.

The windows will often be in a different contractual package from the rest of the wall and therefore effective coordination is required during construction.

The addition of windows into the built-up wall will introduce interfaces between the different elements, *Figure 4.22*. These must be designed and constructed in an appropriate way to ensure that the performance of the wall is not compromised. The complexity of the window installation and the interfaces involved will largely depend on the architectural intent – if the windows project in front of the wall or if there are other features, this will add to the difficulty.

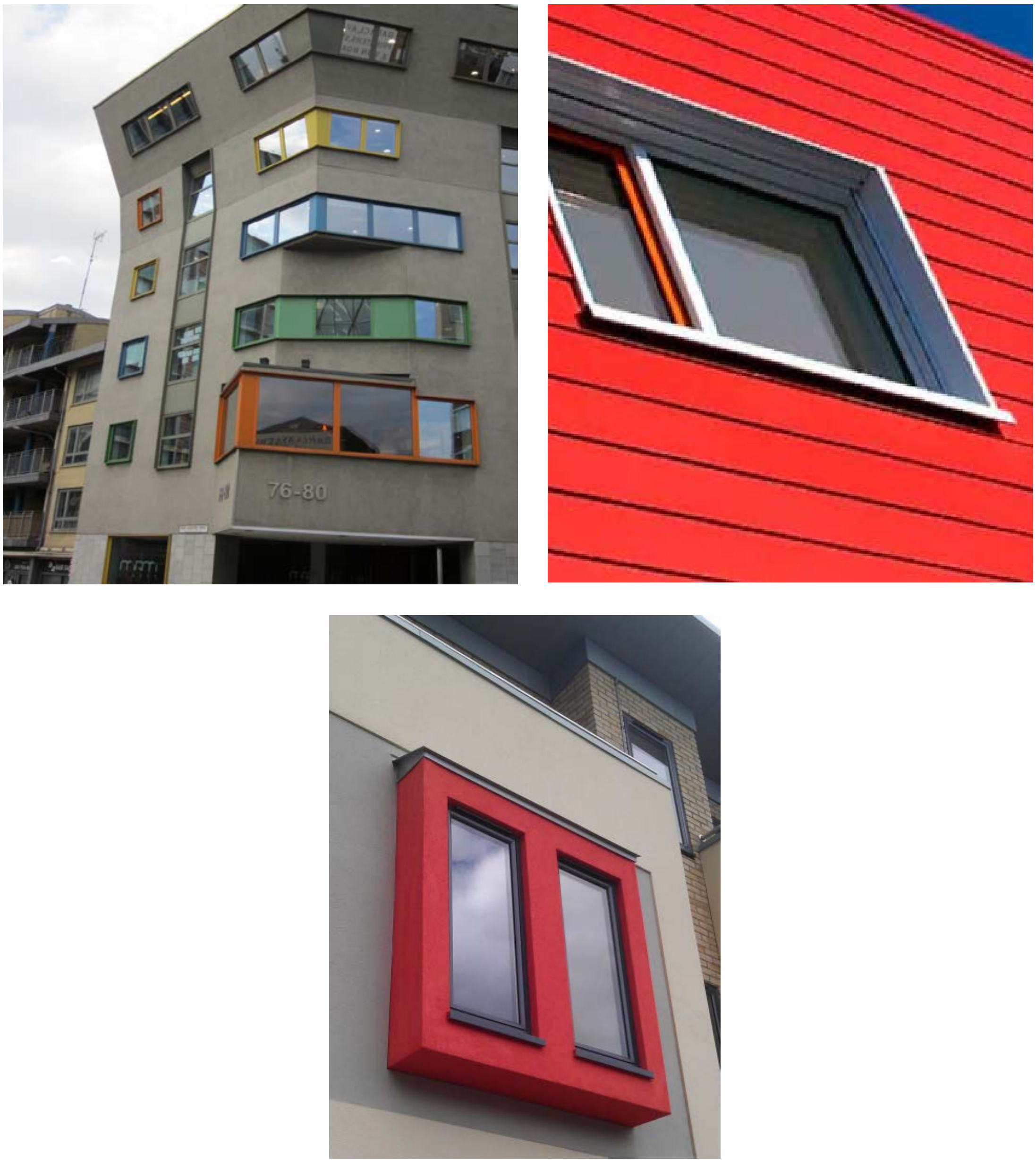


Figure 4.22 - Windows in a built-up wall

Specifying windows is discussed briefly in Chapter 2, and window interfaces with the built-up wall discussed in Chapter 5.

4.2 Rainscreen systems

As described in Chapter 1, a rainscreen wall is one where panels (the rainscreen) protect an air-tight, insulated back wall, with a drained and ventilated cavity between.

A typical rainscreen system comprises:

- panels,
- panel fixings,
- rails (spanning in one or two directions),
- brackets.

Rainscreen panels will typically be selected first based on the architectural intent and budget, with rails and brackets either chosen by default as part of an integrated system or selected to support the panels.

4.2.1 Rainscreen panels

The outer rainscreen panels provide the building aesthetic as well as protecting the inner layers/components of the built-up wall.

The choice of panel will depend on factors such as:

- appearance,
- use/application,
- budget,
- durability,
- maintenance,
- external environment,
- availability/size limitations,
- buildability,
- environmental impact,
- health and safety.

Panels may be uniform in shape and colour. Alternatively depending on the freedom of layout of the support system (rails and brackets), panels may be in different colours and/or shapes and sizes to create interesting visual effects, as shown in *Figure 4.23*.

There is a vast choice of different panel materials and finishes available. Typical panel materials include, but are not limited to:

- metals:
    - aluminium,
    - steel,
    - zinc,
    - titanium,
    - copper;
- composite materials consisting of thin metal skins (most commonly aluminium but other metals are available) separated by a core of polyethylene or mineral material,
- other sheet materials:
    - fibre cement,
    - calcium silicate,
    - high pressure laminates,
    - compressed mineral wool,
    - reinforced polyester,
- timber,
- ceramics, such as terracotta,
- glass,
- stone:
    - composite stone panels with a thin layer of stone bonded to metal honeycomb,
    - natural stone panels.

Figure 4.23 - Rainscreen panels

Depending on the material used, curved rainscreen panels can be produced, *Figure 4.24*. Some panels can be curved on site whereas others have to be pre-formed and brought to site. The minimum radius of curvature achievable will mainly depend on the material used and its thickness – advice from the panel manufacturers should be sought before deciding to use curved panels.

Large metal panels may require additional stiffeners fixed to the back of the panel in order to remain flat. This may induce unwanted visual effects in response to temperature changes. Full-scale mock-ups may be required in order to demonstrate an acceptable appearance.

Interlocking terracotta tiles are available in a range of colours and sizes. The tiles may be solid or cellular and are attached with proprietary fixing clips to aluminium carrier rails. Some systems use standard rails whereas others use system specific extrusions. Retention of the tiles relies on mechanical fixings giving a dry fixed system which does not require the use of mortar or sealant.

Stone has traditionally been used as masonry to form an external facing material for buildings but is now being increasingly used as a non-loadbearing cladding as a result of developments in stone processing which allow stone to be cut into thin panels. Stone types used for cladding are granites, marbles, hard limestones, slates, quartzites, limestones and sandstones that offer a range of colours and surface textures with good durability. In rainscreen applications stone panels are commonly supported by brackets fixed to the back of the panels with undercut anchors and the joints are commonly left open.

Figure 4.24 - Curved rainscreen panels

4.2.2 Panel fixings and rainscreen rails

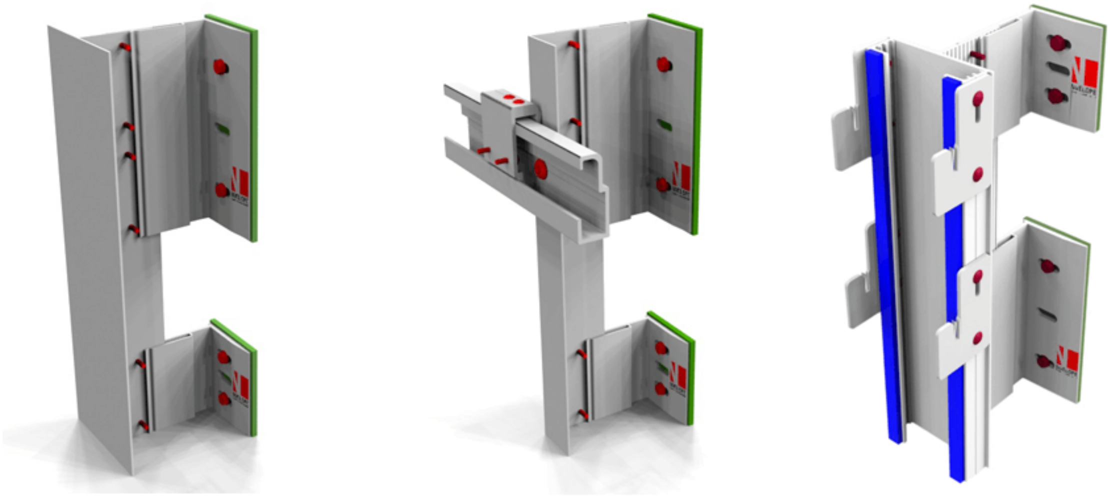
The method of fixing the panel to the back wall will depend on the:

- panel type,
- panel size,
- back wall construction,
- loadings,
- cavity dimension.

Normal systems comprise a lightweight storey height rail fixed to the back wall by brackets at spacings dependent on the loads. Alternatively the rail may be designed to span from floor to floor with brackets fixed to floor slabs. This is more common for refurbishment where the load bearing capacity of the back wall may be questionable.

There are numerous rail configurations available. The most common are:

- T or L shaped rail with face fixing of panels,
- T or L shaped vertical rails with horizontal rails for concealed fixing of panels,
- non-standard extrusions with concealed fixings, for example hook on systems.



Face fixing (a) **Horizontal rail (b)** **Concealed fixing (c)**

Figure 4.25 – Typical rail systems (© NVELOPE)

The simplest panels are formed from flat sheet material and face fixed or bonded to support rails *Figure 4.25*(a). With this method, panel sizes are limited to the size of the sheet available. There is some flexibility with the choice of rail position as the rails do not necessarily have to be aligned with panel edges, although this may be desirable so that the rail seals or baffles the panel joints. Rail centres must also be regular as the fixing points are visible. Panels and rails can be procured separately by the specialist contractor and assembled to form a rainscreen, or the complete rainscreen may be supplied as a system.

Face fixing may not be visually acceptable and can be avoided with thicker sheet material by fixing brackets to the back of the panels with undercut anchors and hanging the panels onto horizontal rails *Figure 4.25*(b). The horizontal rails may either be supported from the back wall by brackets, or more commonly by the vertical rails.

Metal panels can be formed into cassettes which hook onto vertical rails giving a concealed fixing *Figure 4.25*(c). This fixing method normally requires vertical rails to be aligned with the edges of the panels. The rails will need to be purpose designed. For wide panels stiffeners may be bonded to the back of the cassette allowing attachment to additional rails.

Ceramic materials are normally extruded to form tiles and are supplied as a system with extruded aluminium rails and fixing clips.

On smaller, low rise projects, timber battens fixed to the back wall may be used to support the panels. As the battens are fixed directly to the substrate, there little scope for adjustment to accommodate deviations in the back wall.

4.2.3 Rainscreen brackets

Brackets are normally required to support carrier rails from a back wall or framing member, but may sometimes be fixed to the floor slabs.

It is vital that the brackets used are suitable for the proposed application. Amongst the factors to be considered are:

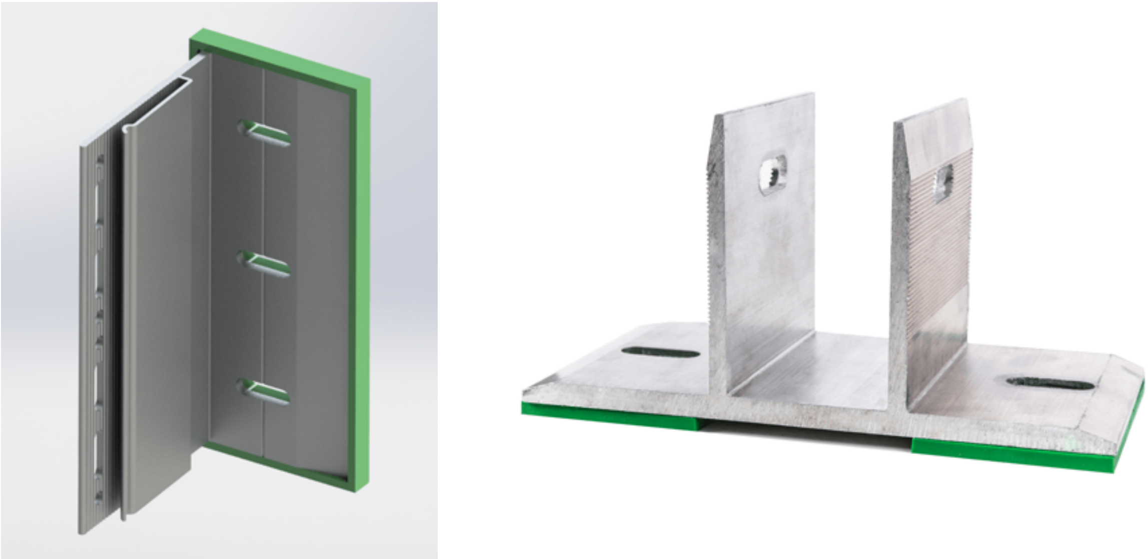
- transfer of loads,
- accommodation of induced deviations (tolerances),
- accommodation of inherent deviations (movements),
- corrosion resistance,
- buildability.

'Helping hand' brackets are commonly used, *Figure 4.26*(a). These are fixed to the substrate at set vertical and horizontal spacings. The rails are then pushed into the brackets and initially held by a spring clip. This allows the rails to be accurately aligned before permanent fixing with rivets or tek screws.

Brackets need to be designed to be able to carry the weight/dead load of the rails and panels in addition to the wind load. The connection between the rail and the bracket must also accommodate movement due to thermal expansion for example. This is typically achieved through the use of brackets with a combination of slotted and round holes through which to fix the cladding rail.

One bracket on each section of rail will carry both dead load and wind load using the round holes in the bracket to fix to the rail. The other brackets provide wind restraint and permit vertical movement using the slotted holes. It is important that the fixing of the panels to the rails also allows transfer of load whilst allowing for movements. This is discussed further in Chapter 6.5.4.1.

Heavier duty brackets are required where they are only fixed to the floor slab, due to the extra loads they must carry, *Figure 4.26*(b). The rails are also more substantial, and secured using bolts rather than screws or rivets.



'Helping hand' bracket (a) **Floor to floor bracket (b)**

Figure 4.26 – Typical brackets (© NVELOPE)

The depth/projection of the bracket will largely depend on the thickness of insulation required in the cavity. Standard brackets are typically available up to 400 – 500 mm depth, but deeper brackets are possible as a bespoke solution.

Horizontal bracket spacing will depend on the loads involved (dead load from the weight of the panels, live load due to wind etc.), stud spacing in a framed back wall, and panel sizes, and will typically be upwards of 400mm. In addition to brackets/rails at panel joints/interfaces, intermediate supports may be necessary for larger panels.

Vertical bracket spacing will also depend on the carrier rail type. For example, lightweight rails will require a greater number of brackets at closer centres.

The correct bracket should be selected for the type of back wall construction/substrate. For example the fixing requirements (bolt-hole number, position and size) could be different when being attached to masonry with expansion anchors or a steel stud wall with self-tapping screws, *Figure 4.27*.

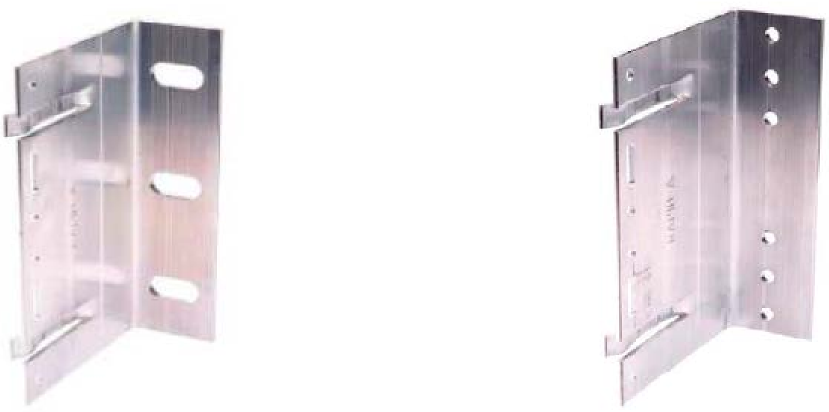
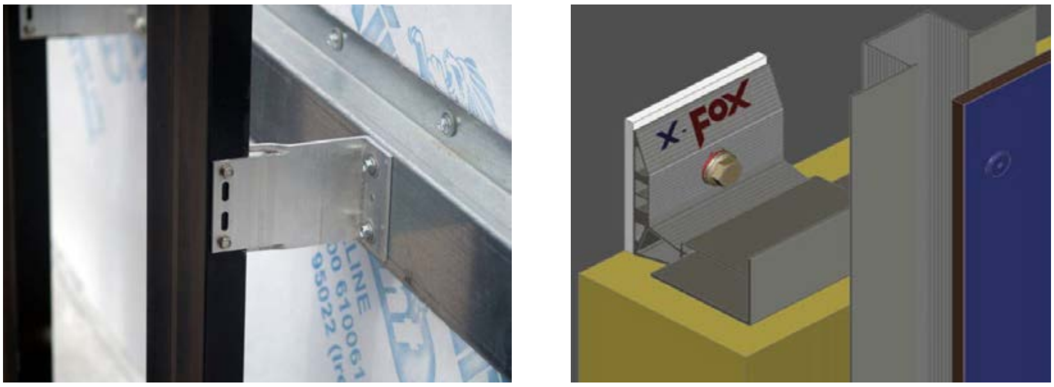


Figure 4.27 – Typical bracket for masonry (left) and stud frame (right) (©Downer Cladding)

The type of back wall used is also important in terms of bracket placement. With a solid back wall brackets can essentially be placed anywhere whereas with a steel stud back wall, bracket placement should be coordinated with the stud positions. Brackets normally need to be fixed directly to the studs in the back wall, however if the stud location does not match with the required bracket position (due to panel size for example), additional components may be required to transfer the load to the studs.

Two possible solutions are shown in *Figure 4.28* below. Firstly, a horizontal top hat section is fixed directly to the studs of the backing wall, onto which the rainscreen brackets can be attached wherever they are required. The second approach shown is to fix the bracket at the stud locations and connect a horizontal rail to the bracket. From this the vertical support rail can be attached at the correct locations for the panels. Both methods introduce additional cost, installation complexity and potential additional heat transfer due to the extra metal components within the insulation. Alternatively, where the construction of the back wall is coordinated with that of the rainscreen, additional studs may be incorporated in the back wall at the cladding rail locations, thus avoiding the need for horizontal rails.



©Downer Cladding ©EUROFOX

Figure 4.28 - Different solutions for brackets into a framed backing wall

Another approach is to fix the brackets directly to the sheathing boards. If this approach is taken the sheathing must be appropriately engineered in order to ensure that fixings have adequate pull-out strength and that the sheathing boards can accommodate cyclic wind loading etc. This will often involve the use of thicker sheathing, which will have a cost and weight penalty. This approach is not recommended.

The situation shown in *Figure 4.29* should be avoided. The fixings for the bracket were intended to go into the stud but due to poor workmanship they were just fixed into the sheathing boards. This resulted in fixings that were unable to carry the loads imposed upon them. If an opaque membrane is applied over the sheathing board, the position of the studs should be marked on the membrane so that position of the brackets can be set out appropriately.

Figure 4.29 - Fixings into the sheathing board rather than the steel stud

Horizontal carrier rails may also be required for certain panel types and fixing arrangements, such as hidden fix systems whereby the panels hang from horizontal carrier rails attached to the main vertical cladding rails. An example of a hidden fix system is shown in *Figure 4.30*. The photograph on the left shows a bracket fixed to the back of a panel. The photograph on the right shows rainscreen panels with brackets hooked over a horizontal rail. The bracket has a levelling screw to facilitate adjustment of the panel location and a locking screw to prevent movement of the panel when the correct position has been obtained.

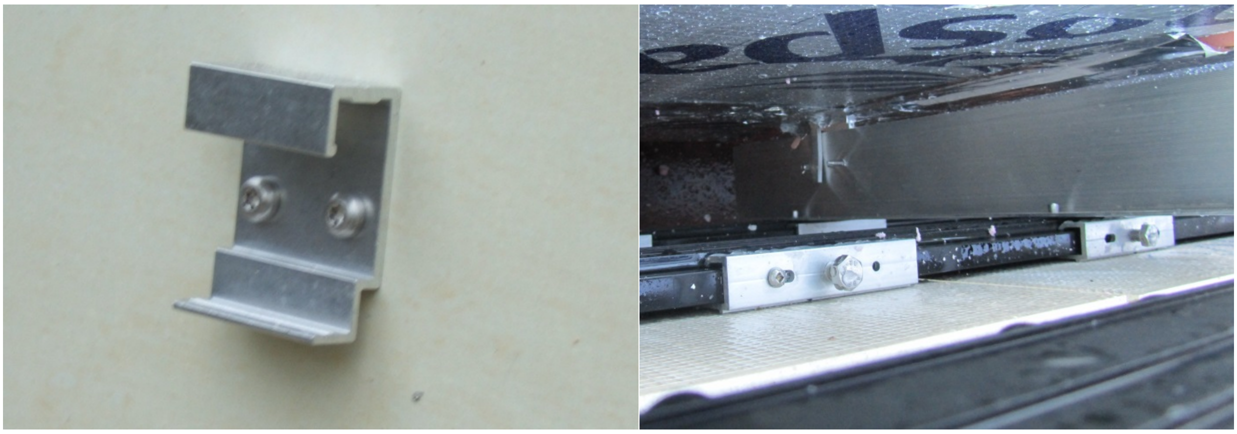


Figure 4.30 - Panel fixing with bracket fixed to back of panel

Brackets are usually made from aluminium. When compared with steel, aluminium has advantages such as lighter weight, better corrosion resistance and the ability to be formed into more intricate shapes. Its downsides include a lower strength (which is not often critical) and much higher thermal conductivity. Thermal pads/separators between the brackets and the back wall may be used to reduce the heat loss caused by the thermal bridge that is the bracket, *Figure 4.31*.

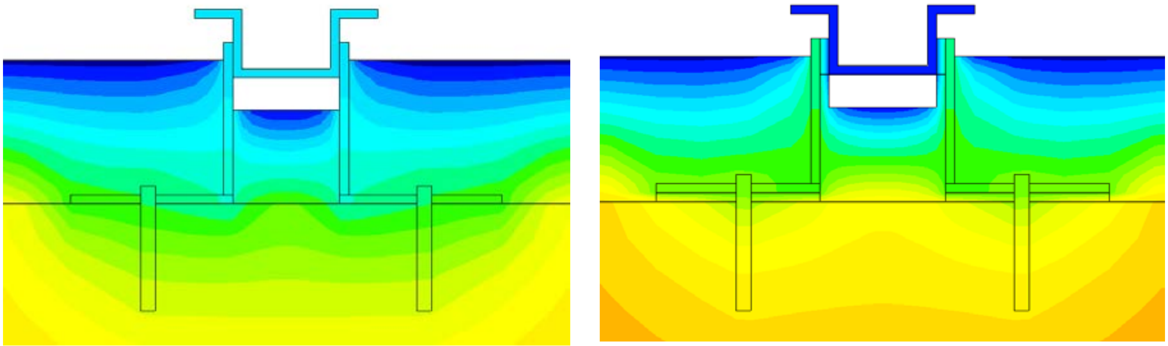


Figure 4.31 - Temperature distribution of aluminium bracket without (left) and with (right) a thermal separator

Care must be taken to avoid issues such as bimetallic corrosion when using dissimilar metals, and other corrosion mechanisms such as alkali attack between concrete and aluminium components.

4.2.4 Cavity barriers and firestops

Cavity barriers may be required:

- to limit air movement behind the rainscreen to create a pressure equalised cavity, see Section 3.2.4.2,
- to control spread of fire in the cavity, see Chapter 6.6,
- to limit gross air movement in a drained and ventilated cavity at corners of the building where large changes in external wind pressure occur.

Cavity barriers to control air movement must be permanent but fire barriers are only required during a fire.

There is a potential conflict between the use of cavity barriers and the need to provide drainage and ventilation of the rainscreen cavity. This is not a problem for vertical cavity barriers and these may be formed by the vertical cladding rail (if the rail is embedded in the cavity insulation), or it may be an additional component such as a mineral wool batt wrapped in polythene.

For horizontal cavity barriers which are required to be permanent it is necessary to provide a cavity closer which drains the cavity, as shown in *Figure 4.32*(a). For cavity barriers which are only required to control fire, the use of a firestop with an intumescent strip will maintain drainage of the cavity under normal circumstances but close in the event of a fire, *Figure 4.32*(b)

Cavity barriers should be positively fixed in position to ensure their effectiveness. Cases of barriers sliding off spikes and collecting at the foot of the cavity have been reported.

A rainscreen cavity is defined as a moist zone and therefore cavity and fire barriers must be durable under such conditions.

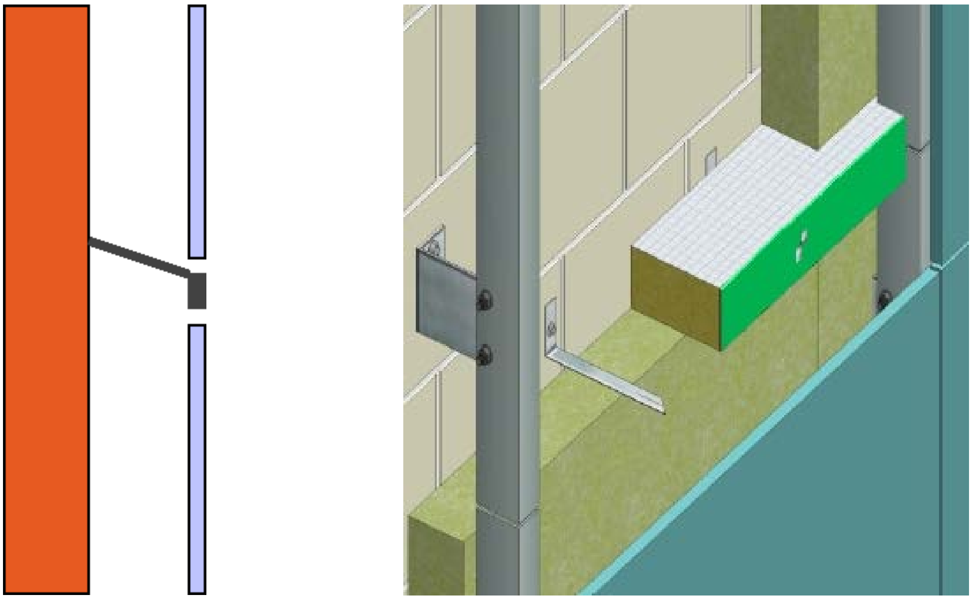


Figure 4.32 - Horizontal cavity barrier/closer (left) and firestop (right) (©Lamatherm) note tails of spike have been bent over to secure the barrier

4.3 Render systems

In addition to the elements described in Section 4.1, the following additional components may be used in the construction of an EWIS.

4.3.1 Renders

The render layer provides the decorative appearance of the wall and protects the insulation from mechanical damage. In addition, it acts as the first layer of defence against water penetration into the wall. It is therefore vital that it is applied according to the manufacturer's specification and that it is appropriately detailed, in particular around penetrations and openings such as windows and doors, and at interfaces with other elements, such as the roof of the building. This is especially true in walls which do not incorporate a cavity in the build-up.

Render materials and technologies have advanced significantly over the years.

Render materials used for external insulation are generally proprietary materials which may be:

- cement based;
- polymer modified cementitious materials;
- polymer based materials.

Polymer and polymer modified cementitious renders are used in thicknesses from a few millimetres up to 16 mm, whereas conventional cementitious renders are used with a metal lathing in thicknesses of 25 mm or more.

Thin coat renders are technically advanced and offer a number of advantages over more traditional render formulations. They are:

- more flexible:
    - more resistant to cracking due to movements/deflections of the backing wall,
    - more impact resistant;
- lighter weight.

Their properties can also be enhanced by the addition of other materials to the render mix such as silicone which gives better water shedding and breathability.

Thin coat renders are non-hydraulic meaning they set by drying rather than by the hydration of cement. This means that the render must be allowed to dry after application which may involve the façade having to be adequately protected for this to happen. Quick drying versions of some thin coat renders are available, which are particularly useful when the weather is cold and wet, or where the humidity is high.

When render is applied to the insulation the applicator must work to a wet edge to ensure a consistent finish. Therefore, depending on the size of the project and its configuration it may be necessary to design in breaks/interfaces in the render coat as construction joints.

BS EN 13914-1: 2005 – *Design, preparation and application of external rendering and internal plastering - Part 1: External rendering* gives general guidance on the use of external renders.

Render materials should be CE Marked where appropriate. Renders with mineral binders should conform to BS EN 998-1: 2010 - *Specification for mortar for masonry. Rendering and plastering mortar*, renders with organic binders (synthetic resin render, silicone render) should conform to BS EN 15824: 2009 - *Specifications for external renders and internal plasters based on organic binders*.

4.3.1.1 Render materials

The main base materials used in external renders are:

- cement;
- acrylic;
- silicone.

Cement based renders are the least technically advanced of the commonly used render materials. For external insulation they are usually used in conjunction with a metal lath. This lathing is intended to support the render and control cracking. They are applied in thick build-ups of typically 25mm or so.

Cement based renders are very stiff and therefore more prone to cracking under heavy impacts than other renders. When used as described above, a strong mix is required to protect the lathing from corrosion. This results is a relatively impermeable render which may cause water vapour to be trapped within the wall resulting in interstitial condensation. Cement based renders have a relatively high water absorption so care must be taken when using them in areas with high exposure to driving rain.

Thicker, more traditional cement based renders are still commonly used for projects such as social housing where cost is a key factor, however even here there is a move towards the thinner render systems with the performance advantages they can offer.

Polymer modified cementitious renders give the traditional appearance of a cement-based render, but with improved properties. They generally have improved bond strength, greater flexibility, increased resistance to water absorption and greater freeze-thaw resistance compared with traditional cementitious renders. They are typically applied in one or two coats, 6 – 16mm thick.

Acrylic based renders are used in thin coats (see Section 4.3.1.2), with a thickness typically equal to the grain size of the aggregate used in the mix. The general properties of acrylic based renders are:

- very low water absorption;
- more flexible than cement based renders resulting in better performance under impact and due to movements of the back wall;
- good adhesion to the substrate;
- not as breathable as cement based renders, meaning care must be taken to reduce the risk of interstitial condensation forming.

In addition, they are available in a wide range of colours to suit most projects.

Silicone based renders provide the highest level of water repellency making them suitable for coastal regions or areas exposed to harsh weather conditions. They are also highly breathable, increasing the rate of moisture transfer and evaporation from the wall.

Silicone based renders are available in a wide range of colours, however the range is more limited than those for acrylic based renders. They are also not as flexible as acrylic renders.

Silicone is also the basis of self-cleaning renders which are available from some manufacturers. Such renders exhibit a hydrophobic nature causing water to bead and run off the surface, taking dirt with it, these renders will be discussed further in Chapter 7.

4.3.1.2 Thin coat render build-up

The general build-up of a thin coat render is shown in *Figure 4.33*. The exact build-up will depend on the render used, the back wall construction and the building type amongst other factors. Manufacturer's instructions should always be followed to ensure the render build-up will be suitable and durable.

A base/reinforcing coat is first applied onto suitably prepared insulation. The insulation should be smooth and tightly butt-jointed. Any open joints between insulation panels should be filled before application of the base coat. Depending on the materials involved it may be necessary to roughen up the insulation in order to provide a key for the base coat.

A reinforcing mesh is pressed into the wet base coat and the material is then smoothed. The reinforcing mesh is typically glass fibre and it should be ensured that the mesh is completely embedded. An additional application of the base coat is not normally required but may be needed in some cases to provide full coverage. The mesh reinforcing strips should be overlapped by approximately 10cm at each edge. The drying time of the base coat depends on the thickness and type of material used, as well as the environmental conditions.

Once the base coat is dry the top/decorative coat can be applied. This should be done according to the manufacturer's specification to ensure compatibility between the materials used. In some cases, a primer coat may be required before the application of the final layer of render. The thickness of the top coat will depend on the finish that is required. Drying time will again vary, but may be up to 14 days, during which time the surface must be protected from wetting.

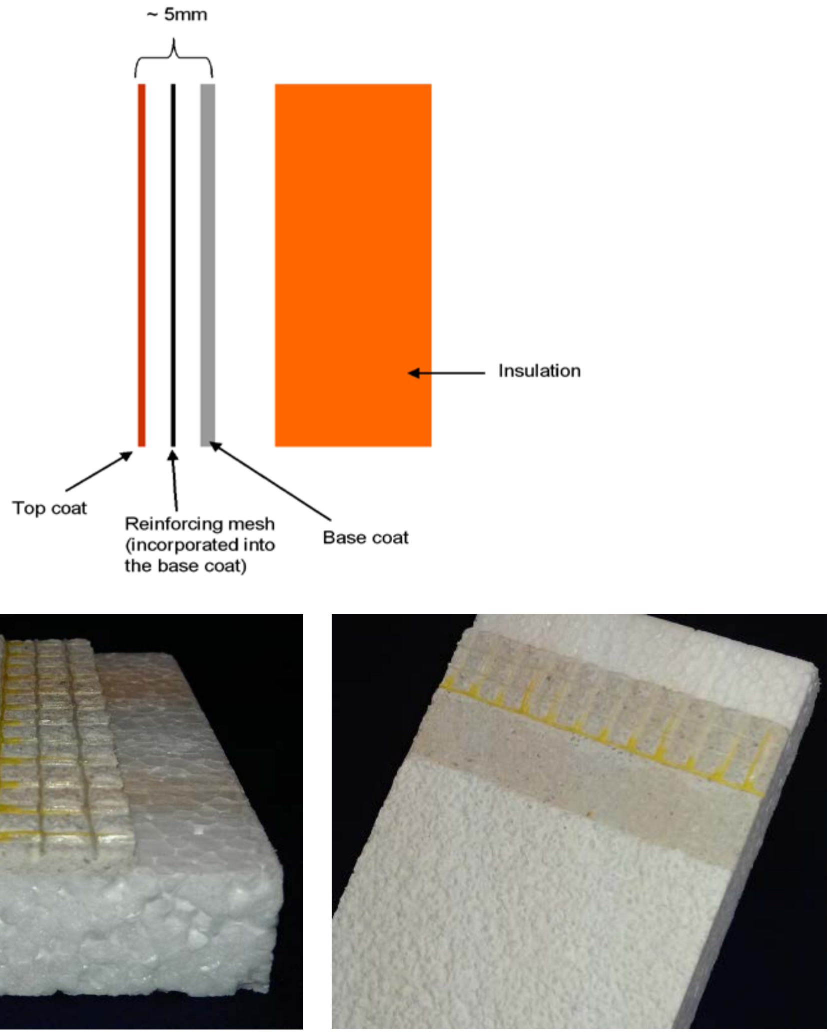


Figure 4.33 – Thin coat render build-up

4.3.1.3 Render carrier boards

The sheathing boards discussed in Section 4.1.1.2.2 may also be used as a render carrier in an EWIS which incorporates a drainage/ventilation gap on the cold side of the insulation *(Figure 4.34*). When used as such, important considerations for the suitability of the boards include:

- compatibility with the render material;
- dimensional stability;
- impact resistance.

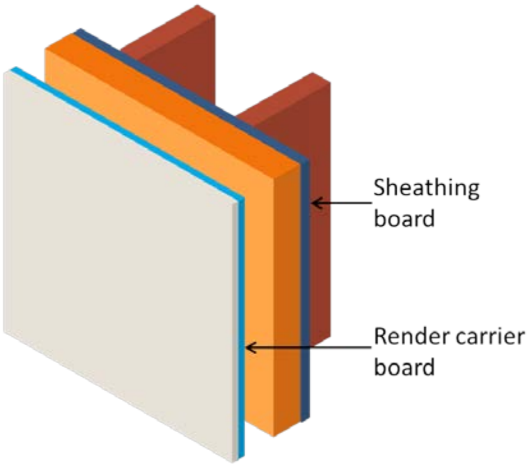


Figure 4.34 – Render carrier board

4.3.1.4 Finishes

Renders are available in a variety of different colours and textures, which in addition to influencing the aesthetics of the wall may also affect the performance.

In general, the greater the texture of the render the less noticeable any cracks arising from minor structural movement will be, as the render tends to disperse into a greater number of fine cracks rather than a small number of wider cracks. Smooth/finely textured renders will therefore show cracks more easily. In general synthetic renders are much more crack resistant than cement based renders as discussed in Section 4.3.1.1

Renders may be tooled to give a textured/patterned finish, or else exposed aggregates can be used to give texture, as shown in *Figure 4.35*. The grade of aggregate will determine the final finish, with coarser aggregates with larger grain sizes giving greater texture. Coloured aggregates can also be used to enhance the appearance of the final wall. In general, the grain size of aggregates is between 1.5 and 6mm.

A textured finish helps to give a flatter and more uniform appearance to the wall as small undulations in the substrate and trowel marks etc. can appear reduced. If a very smooth render is required the level of surface preparation required to minimise imperfections is much greater and the skill level needed of the applicator is much higher, in order to give the desired level of finish.

More highly textured renders may become dirty more quickly and may therefore require more frequent cleaning.

Renders are available in a wide variety of colours. There are two different approaches to this. Firstly, a through-coloured render may be used. This may prove to be more durable as minor scratches etc. will not show up and it will require less maintenance over the lifetime of the façade. Similarly, if graffiti have to be removed the base colour of the render will match the rest of the wall, avoiding the need for additional repair work etc. The availability of colours depends on the render which is used, as different renders have different pigment carrying capacity it is important to check that the desired colour is available in the material chosen.

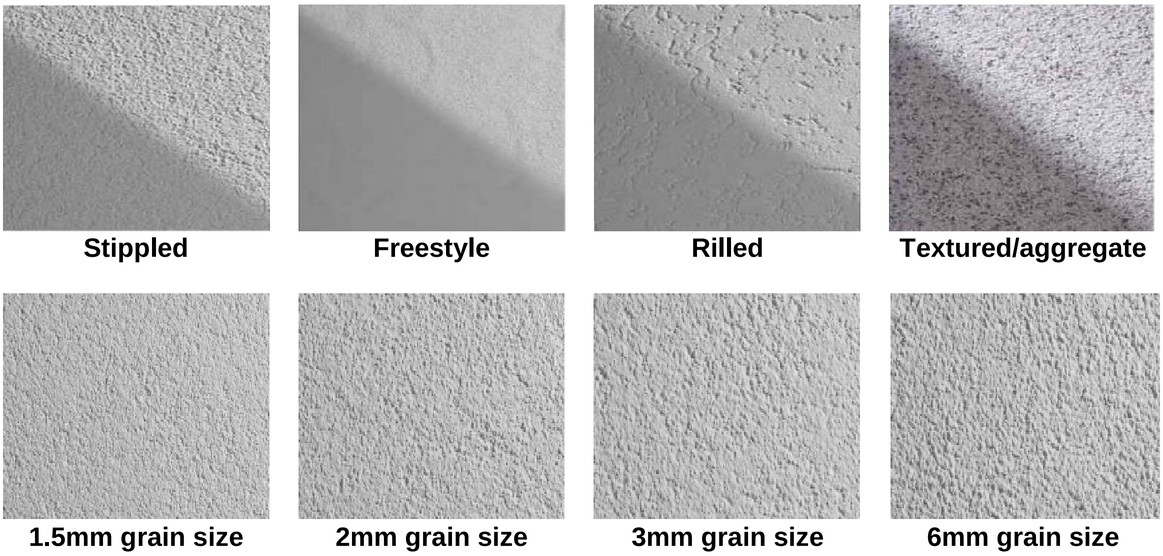


Figure 4.35 – Examples of render finishes © STO

The alternative solution for a coloured finish is to paint the render. It is vital that the paint used is compatible with the render so that it will adhere properly and is breathable so that it will not trap moisture within the wall. Having to paint the render adds an additional stage in the application process so will therefore take longer and may be more expensive. It will also require greater maintenance throughout the life of the wall.

There may be some colour variation between different render types and different batches of render of the same colour. It is therefore important to plan application carefully to try and ensure that a consistent colour can be achieved.

The colour of the render will also have an impact on the appearance and performance. Light, reflective colours will show imperfections in the surface more easily, when compared with darker, matt colours. Darker colours will absorb more solar radiation than light surfaces and therefore they will become hotter. This may cause greater movements in the render and insulation layers that must be able to be accommodated.

4.3.2 Fire barriers

Additional components in the form of fire barriers maybe required to;

- Meet the prescriptive requirements of the Building Regulations;
- To pass relevant fire tests.

Fire barriers may also be incorporated as best practice in a wall than contains combustible insulation.

The solution employed will depend on the materials used in the wall and whether or not there is a cavity within the build-up. Potential details are shown in *Figure 4.36* below.

Where a cavity is incorporated into the wall there is a conflict between providing drainage and ventilation, and fire spread. Intumescent materials are often used to meet these two requirements.

Figure 4.36(a) shows an example where the cavity is between the back wall and the insulation. The rails used to support the insulation have perforations in them to allow water to drain down the cavity. An intumescent material is used to block/cover the openings in the rails during a fire to limit the spread of flame in the cavity. The rails used to support the insulation are stainless steel as opposed to plastic, and combustible insulation is replaced by mineral wool.

Figure 4.36Figure 4.36(b) shows a system without a cavity. In this instance the polystyrene insulation is replaced with mineral wool at floor slab/compartment level which provides the required fire resistance.

The fire performance of built-up walls is discussed in more detail in Section 6.6.

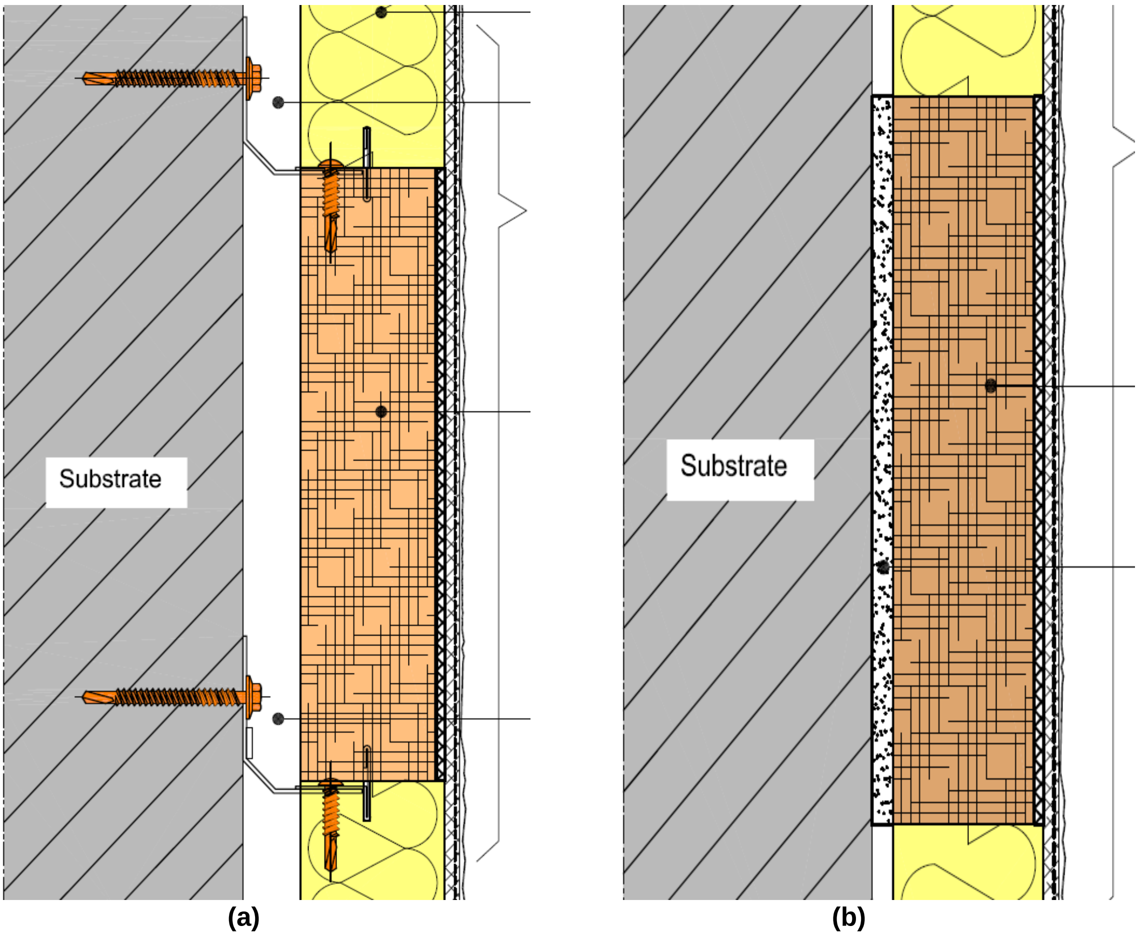


Figure 4.36 – Different firestopping solutions (© STO)

4.3.3 Reinforcement

As discussed in Section 4.3.1.2 some form of reinforcement is required in all render build-ups, usually a lightweight glass fibre mesh embedded in the base coat.

For particularly vulnerable areas of wall, such as zones with high impact or mechanical loads, a heavyweight mesh may be embedded in the base coat to improve durability. Depending on the system which is used, the standard lightweight mesh may have to be applied as well.

An additional diagonal reinforcement mesh must also be used on building openings (windows and doors), as shown in *Figure 4.38*. These areas are subject to higher forces than other areas of the façade and this helps to control cracking of the render in such locations such as shown in *Figure 4.37*.

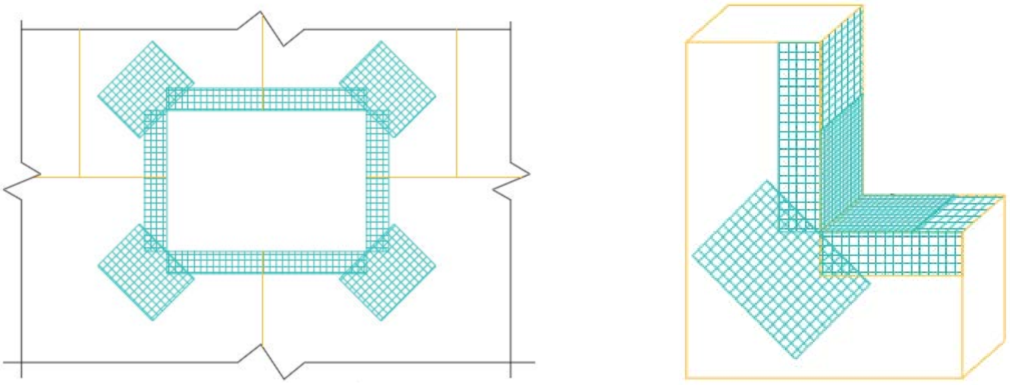


Figure 4.37 – Additional reinforcements at window corners

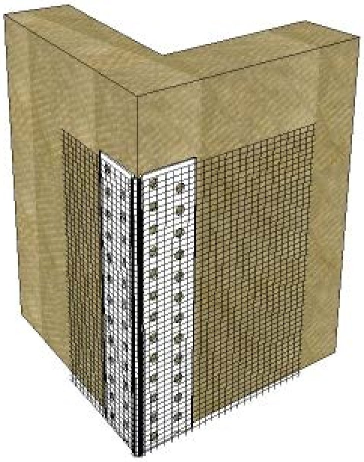
Figure 4.38 – Render cracking at window corner

4.3.4 Trims etc.

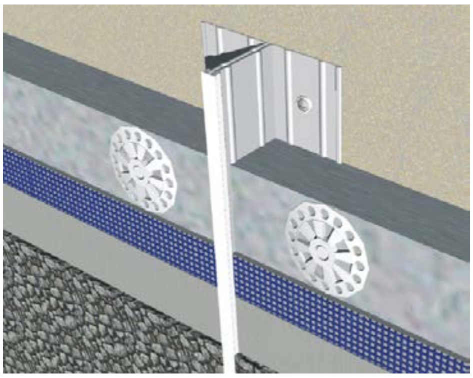
To ensure that water cannot penetrate at edges and junctions, and to give a consistent finish, various trim pieces/beads (*Figure 4.39*) are required within the render build up.

Advice should be sought from the render manufacturer as to exactly what is required for the particular render build up, material, insulation and substrate.

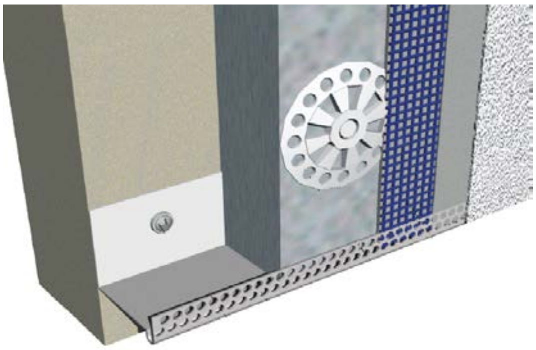
Render stop bead (© Trueline)



Corner bead (© Trueline)



Movement/expansion profile (© Envirowall)



Starter track (© Envirowall)

Figure 4.39 – Trim pieces

5 INTERFACES

The design and construction of interfaces in any built-up wall is of critical importance to the long-term performance of the wall. In *Technical Note 78 Interfaces and joints – Introduction* CWCT makes a distinction between interfaces and joints.

An interface occurs between different forms of construction in the building envelope, normally with outer and inner joints that comprise the interface. Where not occurring within an interface, a joint occurs between components, or within a component of construction.

An interface shall be regarded as both:

- Physical
- Contractual

Whatever the state of the art in the manufacture of construction materials, products, systems, elements and spaces that are expected to be integrated into building entities, it is important that the interfaces between them are addressed both physically and contractually to ensure they are managed, designed and constructed correctly. Interfaces between components must provide weathertightness and are of architectural significance.

The physical interfaces between contractors, and the physical joints that are within the contracted scope of works, must achieve the fenestration of the architectural concept or design intent. This may be dimensionally repetitive, or highly differentiated in geometric arrangement to a point of being considered non-repetitive. Interfaces with selected faces of windows, doors and curtain wall will be in line with or at offsets to the face of the adjacent cladding. The architect will largely determine the intended cladding face and the edges of the interface with any depths of sill, reveal and head to the windows, doors and curtain wall.

It is recognised that the physical and contractual permutations of interfaces may multiply on a project when arrangements of fenestration and multiple cladding systems are combined with several structural options. Interfaces with roofing, balcony, or ground level waterproofing represent additional complexities, as do attachments and penetrations through the cladding.

These permutations must be rationalised to a manageable number of identified interfaces by the design consultants. The task is not impossible or infinite. The design development of interfaces is always a reductive and finite exercise, best undertaken at least conceptually at the early work stages before any application for planning approval.

Built-up walls may cover large areas of flat, uniform façade. In these instances there are few interfaces. Construction time can be quick, high levels of thermal insulation can be provided and a wide range of external finishes is available. The overall performance of a built-up wall however will be limited by the interfaces within and adjacent to the zone of uninterrupted construction.

Interfaces will disrupt the air barrier and waterproofing of a built-up wall. Unintended water ingress and air infiltration or exfiltration will result if measures are not taken to ensure some level of performance at the interface. For example, thermal bridging at interfaces should be minimised to avoid unnecessary heat loss and reduce the risk of condensation forming. This Chapter shall categorise the interrelated aspects of performance that shall be considered at interfaces as a design discipline.

Interfaces tend to be non-standard or bespoke to a project. Architecture is rarely a repeated product, regardless of the substitutability of client or site. Clients frequently hope for uniqueness, and sites are subject to subjective planning decisions. As part of their offer of service architectural practices may have favoured and even signature interface concepts that are repeated across a number of projects, hopefully with improvements made based on the capture of as-built intelligence. The RIBA Plan of Work 2013 explicitly encourages this valuable feedback by recognising that practices work cyclically with projects overlapping. The worst practice is to repeat untested or even failing interface concepts.

Interfaces may fail for a number of reasons, including:

- the interface design concept may have been physically awkward to the extent of being practically unachievable
- the responsibility for the interface is assigned too late if at all;
- the acceptance of the term “by others” on design submittals often leads to the interface being poorly managed;
- the design team does not have appropriate understanding of the generic cladding type or proprietary cladding systems they are proposing to interface;
- the design team does not have an adequate understanding of the construction and manufacturing tolerances of materials and products at the interface;
- the specialist cladding contractors do not have sufficient input to the design of the interface early enough in the programme;
- the cost control decisions, perhaps in the guise of “value engineering” too late in the programme, have underestimated the importance and difficulty of the interface;
- the required interface coordination between different contractors has not happened at a design work stage before manufacture and installation has commenced;
- the sequence of work has not been established or followed to allow contractors to take possession of the interface from those preceding, or handover to those following;
- the site operatives have not been technically instructed, lack the skill, or have not been given the means and time to achieve adequate workmanship at the interface.

In addition to the interface between adjacent elements at junctions and penetrations, interfaces also exist between layers of the wall. The performance requirements for each layer should be clearly specified and design of interface coordinated.

With the potential for different contractors responsible for different parts of interfaces it is important that there is a coordinated handover process to ensure that the wall is constructed to a suitable standard. This requires a coordinated sense of how the works are designed to fit together in a sequence as parts. Successful handover starts with a sensible design concept that is both physically achievable and capable of being the interface between contracts.

5.1 Function of an interface

The functional requirement of an interface is to provide continuity of envelope performance across the meeting of different forms of construction. The different forms of construction may have different levels of performance and the interface is not necessarily required to match the performance of either. For instance, permitted air leakage or thermal transmission may be greater at the interface.

The interfaces shall be designed such that taken as a whole the building envelope gives the required performance for:

- air tightness;
- vapour resistance to prevent condensation;
- thermal insulation;
- water penetration resistance;
- sound reduction, and:
- fire safety.

The interface will be required to:

- transfer loads;
- accommodate tolerances;
- allow movement.

The interfaces in built-up walls with windows, doors and curtain walls will consist of a number of different component products and materials, including:

- air spaces,

- insulations,
- sealants;
- gaskets
- mouldings;
- membranes;
- coatings;
- adhesives;
- tapes;
- fixings;
- straps;
- brackets;
- flashings, and;
- cavity closers.

These functioning components must perform within an interface for a specified service life to a level of maintenance, as discussed in Chapter 7.

It is important to be vigilant against the tendency for product or material substitutions to be made during construction. Sometimes supplies are unavailable, but often post-tender cost savings are sought. The main, management or partnering contractor shall prevent the use of components other than those accepted during the design development work stages, and shall consider component non-equivalence to be redesign. Substitutes shall be notified to the client's consultants and their equivalence fully substantiated and verified in agreement with the interfacing specialist contractors. Claims that alternatives will function "better" than those anticipated in design are unreliable.

5.2 Interface design and construction

In traditional or design and build contracts the main contractor has a significant role to play in the interface handover process between sub-contractors. In management contracts the management contractor or the construction manager will take the lead in allocating trade contracts as work packages, which will be scoped by their interfaces. In partnering contracts the partners will have to explicitly agree their interfacing roles.

Issues that shall need to be resolved will include:

- What are the interfaces on the project?
- Why do contractors need full responsibility for part of the interface?
- When does the sequenced interface need to be constructed in the programme?
- How will the interface works be assessed?
- Where is the coordinated interface benchmark?
- Who has overall responsibility for the design of the interface?

Each sub-contractor or trade contractor should check that the material or product to which they are fixing is correctly positioned and appears to be as the accepted drawings. It should not be the responsibility of one sub-contractor or trade contractor to check the concealed work previously carried out by others.

This is particularly important when construction which affects the integrity and performance of the wall will be covered up by subsequent operations, including the fixing of insulation and the sealing of sheathing boards. Such layered construction shall be identified and checked by the main contractor, management contractor, or partnering contractor before any planned handover and subsequent concealment by following works.

The main, management or partnering contractor plays an important role in coordinating design detailing, assigning responsibility for construction, and overseeing the procedures that are necessary for partial and sequenced handover through to interface completion.

A project should involve:

- A set of drawings or a model identifying where the interfaces are on the project;
- A scope of works allocation that explains who “owns” the interface parts;
- A recognition of the sequence of interface parts in the programme;
- A measure to assess when the parts are constructed as intended;
- A method of acceptance that states each interface is performing as a whole;

The acceptance method might include technical submittals or successful test results, but that will not always be possible. In the absence of objective methods for acceptance the project is reliant on the discipline of the design, the overview of workmanship, and the contract terms.

The performance of an interface or joint will depend upon small components such as:

- flashings;
- membranes;
- sealant joints;
- fixings.

Where interfaces and joints are in a vulnerable location, or may be subject to poor workmanship, such as the application of an external sealant as a water seal, consideration should be given to what happens if the joint fails.

The interface or other type of joint providing an aspect of weathertightness should be designed on the assumption that if the first line of defence against water penetration fails there is a drainage cavity behind and a secondary line of defence further back in the wall. Any water passing the first seal must be safely drained away and directed out by sloped surfaces.

When designing an interface, it is also necessary to consider factors such as:

- buildability;
- maintainability;
- durability;
- movement;
- coordination and sequencing.

When designing joints in the building envelope reference should be made to *BS 6093 - Design of joints and jointing in building construction – Guide*, and *BS 5606:1990 Guide to accuracy in building.* It should be recognised that most joints and interfaces in the building envelope will require more sophistication and tighter tolerances than allowed in these standards.

Buildability
It must be possible to construct the interfaces and joints as intended. If the interface is difficult to construct, workmanship may be compromised and this may lead to inadequate performance in service. The design should be conducive to good workmanship. Contractors will insist that ‘buildability’ starts with a practical design from the architect.

Maintainability
Two aspects of maintenance need to be considered. Clearly it must be possible to rectify any defects in the interface and this is likely to be easier where access can be gained from inside the building.

Details that are concealed from both the inside and outside of the façade may be protected from deterioration but may be difficult to maintain if defects do occur. It may also be necessary to dismantle the interface to rectify faults in other components.

Durability
Deterioration is more likely to occur at interfaces as there may be breaks in the normal protection systems to the cladding materials, they will often be subject to more aggressive conditions due to movements and increased water loading and the interface components such as gaskets and sealants may be prone to deterioration. Interfaces often occur where different components meet and there is a

risk that incompatible materials may be used. For example, sealants can give rise to staining of stone cladding. Compatibility testing should therefore be carried out (sealant manufacturers should be able to offer this). Certain grades of silicone are available which will not cause staining.

Movement
Any movement of the building structure, back wall and cladding must be accommodated in the interface design. This requires the correct materials to be used, an appropriate design and good workmanship.

Coordination and sequencing
Where multiple contractors are responsible for different elements of the wall, coordinating the work so that it is completed in the correct sequence is vital. The exact sequence will depend on the components involved.

Windows are may be installed before an external render is applied, however some windows have to be installed after the render, requiring different interface details and sequence of work.

5.3 Design check disciplines

There are established design disciplines for consultants to employ during the development of functioning interface details. These are useful checks whether working in 2D, 3D or BIM, and in addition to the familiar establishment of samples, mock-ups, prototypes and benchmarks discussed in Chapter 2.

Architects are expected to draw the line of the visual face of the building envelope, and need to be able to define the tolerances expected of that construction. There is:

Line of Visual Face
Defining finished construction in repose before movement, with acceptable tolerances.

Engineers, whether concerned with primary or secondary structure, the façade or the building services, may further advise architects on how toleranced interfaces are associated with differential movements. The architecture will be affected by:

Lines of Movement
Locating the X, Y and Z direction, magnitude, and timing of differential movements.

This intelligence is most usefully collated into a project Movement and Tolerances Report which is sophisticated and checked as the design develops. It is a task that is often given to the structural engineer to initiate, but should involve other consultants in determining the basis of setting out by surveyors, who will be instructed by the contractor in work stage 5.

As a simple test it should similarly be possible to draw a continuous line across the interface to indicate the function of parts. These lines may be coincident. It should be possible to identify:

1. **Lines of Air Barrier**
   Anticipating the Whole Building Airtightness test, as the aggregate of air leakage

2. **Line of Vapour Control Layer**
   Confirming whether the VCL is an Air Barrier, and predicting condensation dew points

3. **Lines of Thermal Insulation**
   Showing steps in U value, thermal bridging and the location of thermal breaks

4. **Lines of Defence against Water Penetration**
   Achieving an effective water barrier for the envelope, including membranes and cavities

5. **Lines of Fire Barrier**
   Maintaining compartments, closing cavities around openings, and dividing cavities

It should be possible to show a contractor, the architect, and the client that the five linear design disciplines have been achieved at identified interfaces. That might take the form of marked up drawing submittals, or represent the culmination of building envelope design workshops on more complex projects.

An example is shown in *Figure 5.1* for the air barrier, vapour control layer and water barrier, however for other permutations of primary and secondary structure to cladding, with windows, doors and curtain wall in other locations, the various lines will be positioned differently.

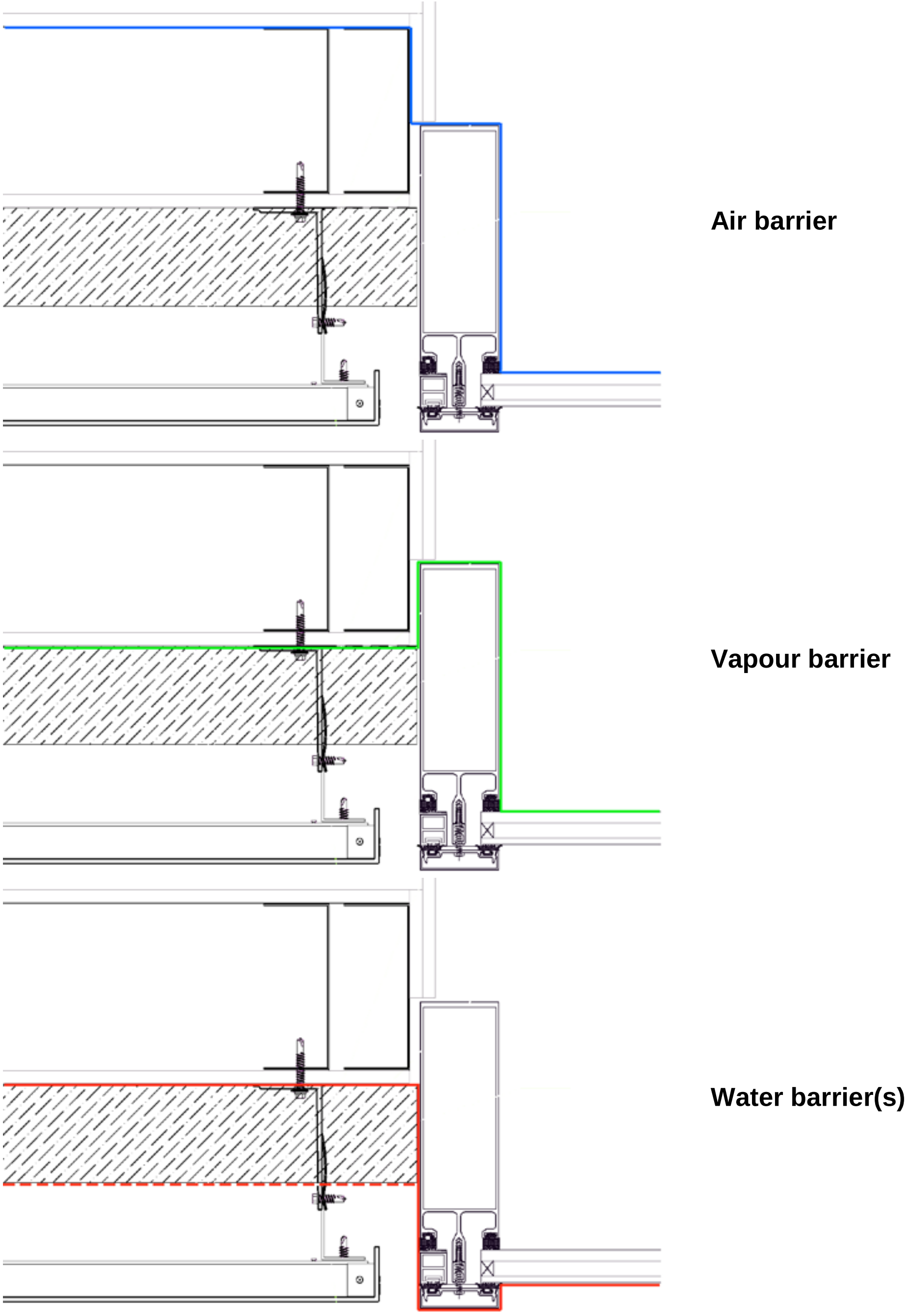


Figure 5.1 - Ensuring continuous air, water and vapour barriers at an interface

It should be noted that:

- the air barrier has to be continuous;

- the vapour barrier has to be continuous;
- the water barrier may be discontinuous provided it is correctly lapped.

5.4 Interface drainage

Like the lines of visual face and movement, all five performance checks apply horizontally on plan and vertically in section or elevation, because they are three dimensional through the building envelope, including the ground and roof.

The shape of the water barrier is important. The water barrier may need to be formed or profiled to provide drainage, ensuring that any water is safely removed from within the wall at identified locations.

The position of the shaped drainage is important. Water run-off has to be managed to the visual face to avoid staining and premature deterioration of materials and finishes. Water from rain or condensation must not become trapped within the building envelope. There are three kinds of drainage to think about in interface design:

- Surface drainage shall be managed in the architectural detailing from the outer line of the water barrier, as in the case of an externally insulated render system.
- Cavity drainage shall be provided within the construction from an inner line of the water barrier, as in the case the insulation face, and the sheathing board that may be covered by a membrane as part of the back wall for a rainscreen system.
- Frame drainage integral to window, door and curtain wall systems shall be accommodated at the sill, reveal and head interfaces.

Water shall be drained directly to the outside of the building, rather than into cavities and other areas of the wall. The sill and head detail of a window in a rainscreen wall provides an example in *Figure 5. 2*. There should be an appropriate flashing detail at the head of the window that directs water draining down the cavity to the outside, rather than horizontally within the cavity. This flashing shall direct all water expected to drain down the backing wall and the insulation face. Similarly, the sill detail at the base of the window should not direct water into the cavity below.

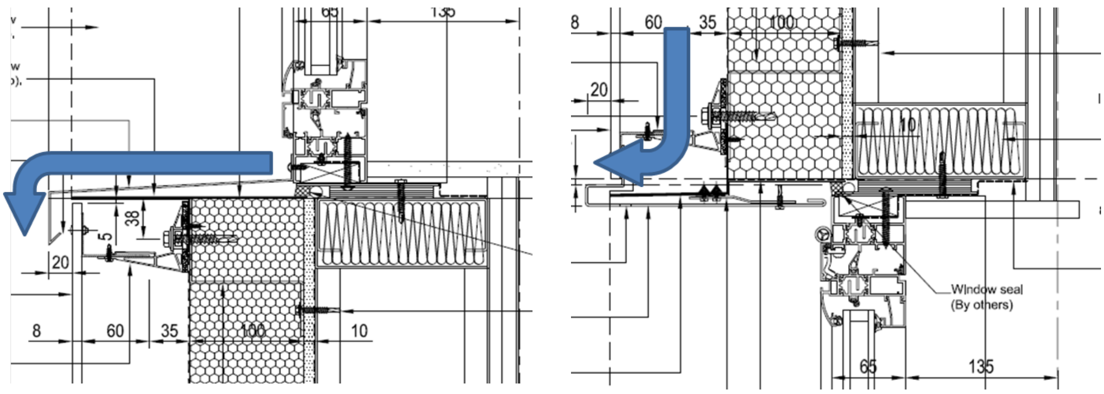


Figure 5. 2 - Drainage path at window sill and head interface

Insulation products used in built up walls must not absorb water to be considered a line of defence against water penetration. Water will not drain if it is absorbed by insulation. This may require the use of a breather membrane on the outer face of the insulation, or using an insulation product with a foil facing.

5.5 Thermal bridging

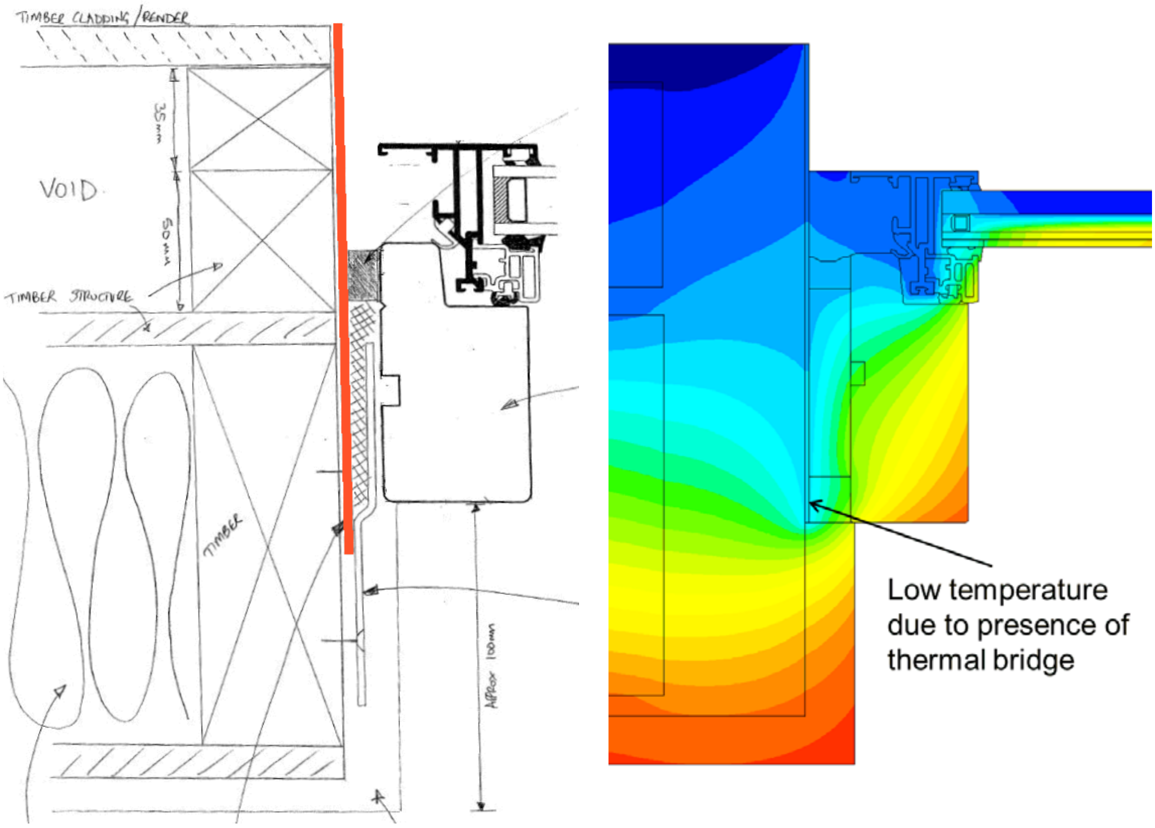
Thermal bridging, resulting in additional heat loss and an increased risk of condensation at interfaces is a significant risk if the junction is poorly designed and constructed. Careful consideration should be given to components such as:

- brackets;
- flashings;
- cavity closers;
- fixings, and;
- window straps.

Thermal bridging is further discussed in in Sections 6.7 and 6.8.

Figure 5.3 shows an example of what can happen if the interface between a wall and a window is not adequately thought through. The aluminium reveal pressing extends from outside back into the wall where it is in contact with the window fixing lugs. This forms a severe thermal bridge resulting in low internal surface temperatures and a significant risk of condensation forming.

In this case the only option other than to remove the windows and start again was to add some insulation and an external reveal pressing, however the improvement would be limited due to the fact that only a very thin layer of insulation can be added.



Interface detail **Temperature distribution**

Figure 5.3 - Poor interface design leading to thermal bridging and severe condensation

5.6 Sealing

Sealing around windows is often reliant upon membranes and site applied sealant joints. In order for such details to be robust requires:

- good design, including appropriate allowance for:
    - movement,
    - tolerances,
    - surfaces to bond to,
    - drainage of cavities;
- good workmanship;
- correct use of materials such as surface primers etc.;
- coordination and sequencing.

Figure 5.4 - EPDM membrane between window frame and sheathing

Figure 5.4 above shows EPDM membranes used to seal the window frames to sheathing boards on the back wall. This method of sealing can be very effective and durable providing manufacturers recommendations are followed during installation. Bonding to the substrate may be by a liquid applied adhesive or by use of a membrane with a self-adhesive strip incorporated.

The substrate surface should be dry, free from dust and loose particles, and degreased. A primer may have to be used if bonding to a porous substrate. There may also be minimum application temperature limitations which must be observed.

Care must be taken when specifying EPDM to ensure that it is not inadvertently creating a vapour barrier to the cold side of the dew point temperature position. Where this is the case, alternative vapour permeable or ‘intelligent’ membranes could be used. Vapour permeability of window interface membranes is discussed further in CWCT Technical Note No. 78 – *Interfaces and joints – introduction*.

Figure 5.4 also shows different approaches to sealing the gaps between sheathing boards, with the image on the left showing a taped joint, and the image on the right a wet-applied sealant. Both methods are heavily reliant on workmanship, and the quality of products used. Where board joints are sealed compatibility between membrane adhesives and the sealing medium should be considered.

Figure 5.5 shows what can happen if the design and construction of the window-wall interface is not properly considered. The image on the left shows a membrane which has not been adequately fixed to the window frame. Adhesive bonding together with mechanical fixings may be required to reliably attach the membrane to the frame; however, the exact fixing method will depend on the frame type/configuration as well as the back wall construction and membrane type. The image on the right shows lapped membranes which have not been bonded together properly.

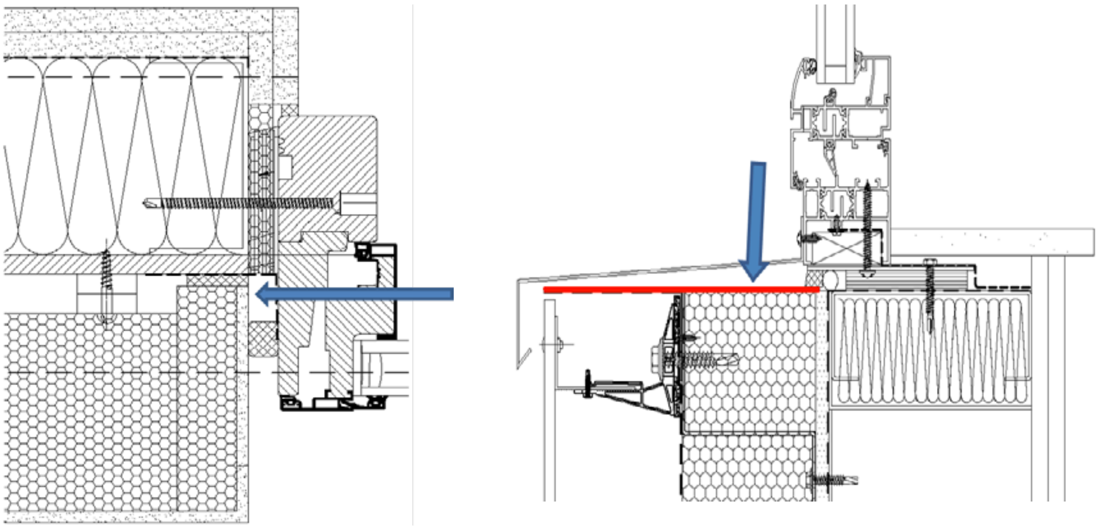
Figure 5.5 - Membrane seals around windows

There is often a cavity created at the interface between a window and built-up wall, *Figure 5.6* (indicated by the blue arrow). This cavity should be drained so that any water passing the outer seal is not trapped within the wall where it may cause long term damage.

Figure 5.6(a) shows a window jamb interface with EWIS. Water trapped in the cavity indicated may cause degradation to the insulation and subsequent failure of the render. This cavity should be drained to the outside at sill level.

Figure 5.6(b) shows a window sill interface with a built-up rainscreen wall. The sill pressing is attached to the front face of the window. Any water getting into the cavity below should be drained. In this case there is a horizontal reveal liner (in red) – this should slope towards the outside to direct water away from vulnerable areas of the wall.

It is recommended that cavities at interfaces are drained.



(a) **(b)**

Figure 5.6 - Drained cavities at window interfaces

Water management may be considered particularly important at interfaces within an EWIS as any water getting behind the render may significantly damage the wall. Additional features which may be used at a window-wall interface include:

- special profiles/beads to ensure there are suitable flat surfaces to bond to around penetrations;
- edge trims to avoid unprotected/exposed render edges.

The performance of sealant joints used as part of an interface is absolutely critical. Typically, such joints (shown in *Figure 5.7*) will be a:

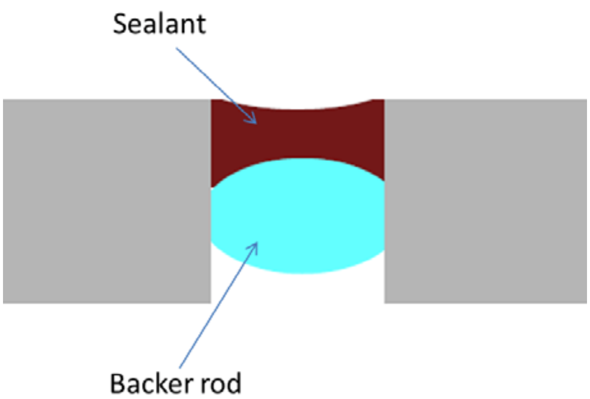
- backer rod and sealant;
- impregnated foam sealing tape.

A backer rod and sealant is arguably the most widely used and reliable method. This method forms an expansion joint to account for movement between dissimilar materials caused by thermal movement and shrinkage. The backer rod is used as a backup material to control the depth of the joint and create proper sealant geometry, allows adhesion on opposite sides thus avoiding three-sided adhesion and aids tooling of the sealant.

As a method of making the installation of sealant joints more economical and to cope with higher levels of movement, impregnated foam sealing tapes can be used. The pre-compressed impregnated tape is supplied with a self-adhesive strip to one face to provide initial bonding to one side of the joint until the tape expands and seals against both sides. These products are usually more economical and quicker to install than the backer rod and sealant option and installation can take place in wet weather and also to damp substrates unlike most 'wet' sealants. Care should be taken to select the appropriate size of tape for both the initial joint dimensions and also anticipated subsequent movement (expansion or contraction). The watertightness of compressible sealant tapes may be compromised by localised protrusions or indentations in the surfaces to be sealed.

A benefit of impregnated foam tapes over conventional 'wet' sealants is their vapour permeability which allows any entrapped moisture to escape to the external environment.

Manufacturers should be able to offer guidance with regard to such interfaces.



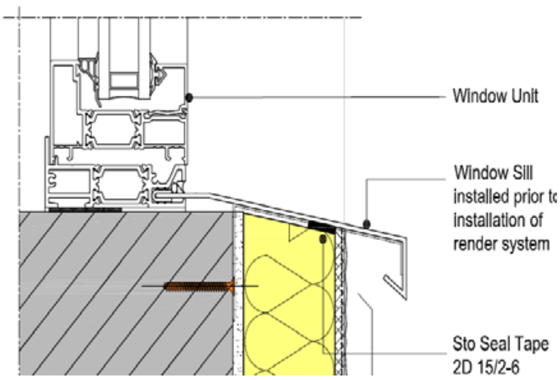


Figure 5.7 - Sealant and backer rod (left), foam sealing tape (right, ©STO), impregnated foam tape seal between window and brickwork wall (bottom)

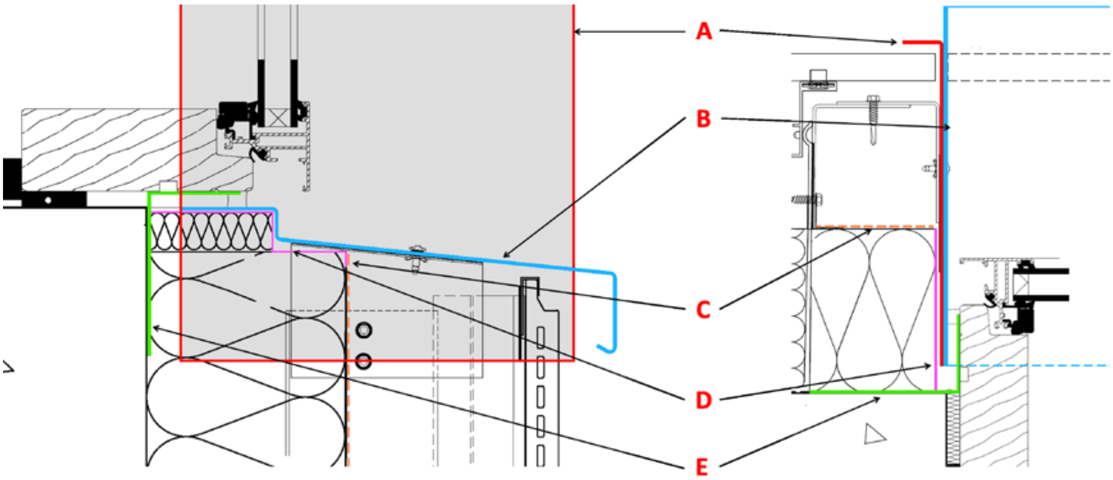
Figure 5.7 also shows an impregnated foam tape sealing between a window and a brickwork wall. The foam tape expands to fill the gap due to the mortar joints between bricks and thus provide a reliable seal. The correct thickness of tape should be used to ensure that the gap is sufficiently filled.

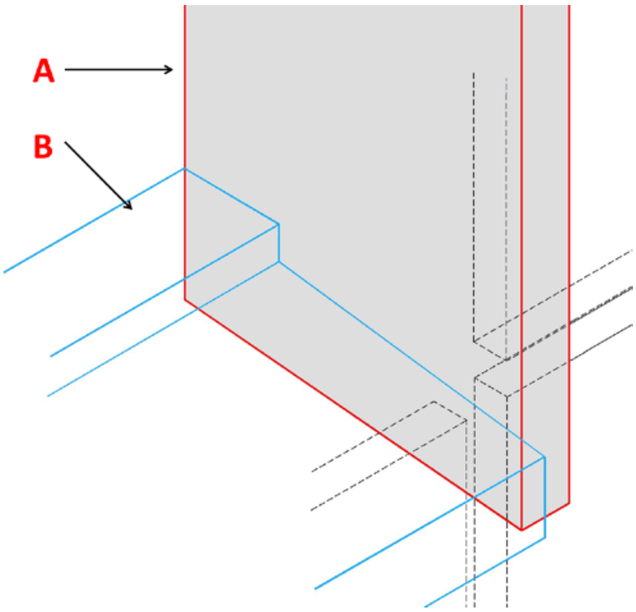
5.7 Window interfaces

Water leakage around windows needs careful consideration. Membranes, tapes, sealant joints and flashings have to be designed to keep water out of vulnerable areas of the built-up wall.

Figure 5.8 shows a possible interface design. A pressed metal sill (B) is fitted under the window frame to close the rainscreen cavity and direct water away from the window. A jamb pressing (A) is also fitted which extends downwards beyond the sill, into the rainscreen cavity below. The joint between the sill and jamb pressing is unsealed, meaning that water may run down the jamb pressing into the rainscreen cavity.

With a detail such as this it is imperative that the materials used below the window, in particular the back wall and the insulation, are able to be wetted, or are protected from getting wet. In the example shown in *Figure 5.8* the back wall is precast concrete and therefore should be robust enough to cope with a little water reaching it. The insulation used is a rigid foam insulation. Even so, the manufacturers state that exposed edges should be protected with an aluminium foil tape (D in *Figure 5.8*). The durability of such an arrangement may be questioned. Nevertheless, it is always preferable for each element, such as a window, to be self-draining and not to drain water into the build-up of another element (e.g. a rainscreen) below.





A	Reveal pressing
B	Sill pressing
C	Breather membrane
D	Foil tape
E	Membrane

Figure 5.8 – Window jamb/sill interface

Figure 5.9 shows an alternative approach to the sill detail. Instead of a simple pressed metal section, a 'pan' is used. This can either be sealed to the jamb opening, or used in conjunction with a jamb pressing over the top. Water running down the jamb is caught in the sill rather than running past. This detail can be made more weathertight by welding the corners of the pan, or having a sealant joint.

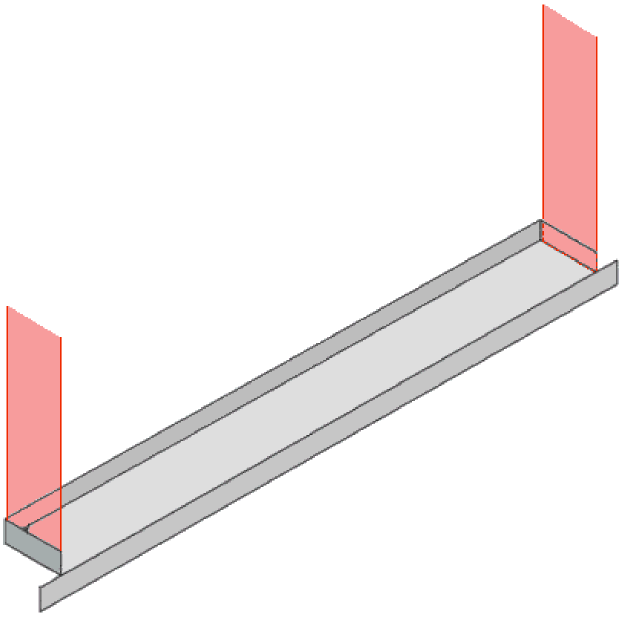


Figure 5.9 – Window sill 'pan'

The above idea can be taken a step further and developed into a window pod, *Figure 5.10*. A window pod may be built up on site, or be prefabricated. The window pod is sealed to the back wall, helping to ensure the continuity of waterproof or vapour control layers which may be fixed to the sheathing, closing the cavity around the window and directing any water to the outside.

Figure 5.10 – A window pod (© SteelConstruction.Info)

5.8 Membranes

A membrane may be used in a built-up wall to provide a:

- water barrier;
- vapour control layer;
- air barrier;
- appearance.

5.8.1 Water barrier – rainscreen

In the UK it is common practice to provide a waterproof membrane within rainscreen walls in new construction. A membrane may not be strictly necessary where testing has shown that the amount of water likely to enter the rainscreen cavity is insufficient to cause significant wetting of the back wall and can be effectively removed by drainage and ventilation before it causes deterioration. In most cases it is easier to provide a membrane than to carry out the required testing. Even where such testing is carried out a membrane may be used to provide an additional safeguard against water penetration.

Depending on its location, a waterproof layer may be required to be vapour permeable or vapour tight, see CWCT Technical Note No. 78 – *Interfaces and joints – introduction*.

A waterproof membrane may be located on the outer face of the insulation or between the insulation and the back wall.

Open-cell insulation may absorb moisture. This will reduce the effectiveness of the insulation (i.e. increase its thermal conductivity) and if enough water is present may soak through and wet the back wall. In such cases a breather membrane is best placed on the cavity side (outside) of the insulation to protect it from wetting, without trapping moisture vapour diffusing through the wall. A VCL should not be used in this position due to the risk of condensation (see later), however one may be used against the sheathing as shown in *Figure 5.11* below.

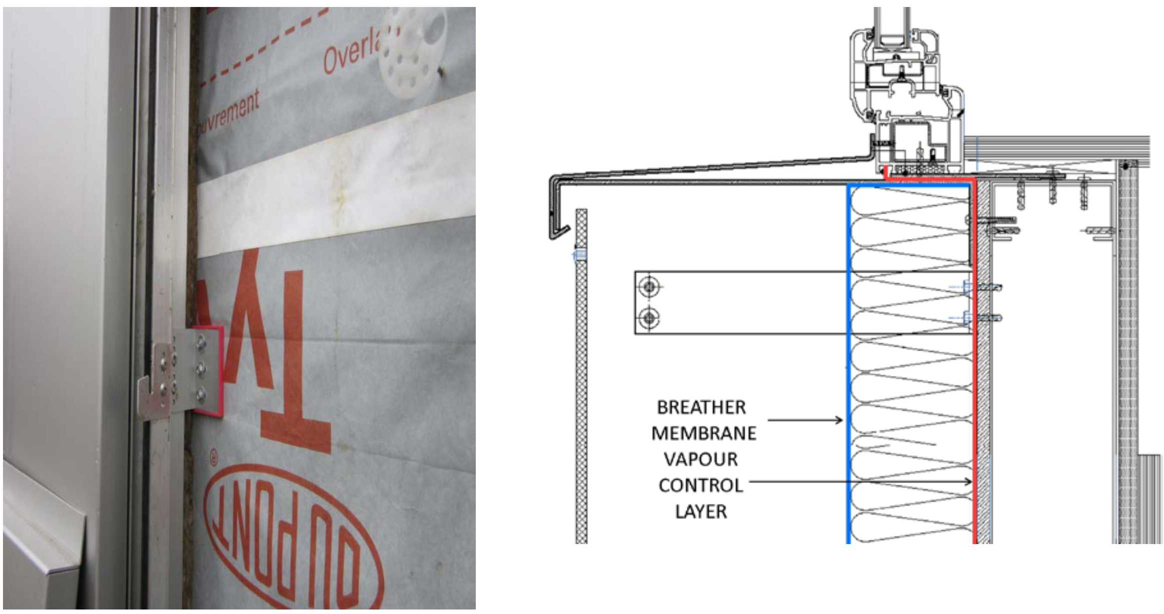


Figure 5.11 – Waterproof membrane against sheathing (left), waterproof membrane on outer face of insulation (right)

Where the back wall contains insufficient insulation for the dew point to be within the back wall, the main thermal insulation is in the cavity external to the back wall and the cavity insulation is tolerant of wetting (for example a foam-plastic insulation such as phenolic foam, or mineral wool with water repellent additives), a single membrane could be used behind the insulation to provide the water barrier. In addition, this membrane could also act as the air barrier and vapour control layer. This layer is in the warm zone of the wall and therefore a membrane in this position should not result in interstitial condensation.

This is usually a very economic and reliable form of rainscreen built-up wall construction as a single membrane can be used as the air, vapour and water barrier. The membrane can be readily made continuous, uninterrupted by floor slaps and robust materials can be used. There is a disadvantage with this form of built-up wall construction in that with most (or all) of the insulation being in the cavity the overall wall built-up is thicker than if insulation is positioned within the framed back wall.

A water barrier may be created by the use of foil faced insulation with taped up joints, *Figure 5.12*. This may be in addition to or in place of a separate membrane. Care is required with this approach as it will be necessary to seal all penetrations at bracket locations in addition to joints in the insulation. Failure to seal some of the joints/penetration could allow water ingress and fail to provide a means of subsequent escape. A further issue is the possible creation of a vapour tight layer on the cold side of the insulation which could cause condensation. If the insulation is a foam plastic material its vapour permeability may be sufficiently low to prevent condensation over the areas of the insulation boards but vapour may penetrate at joints between the boards, if they are not tightly butted.

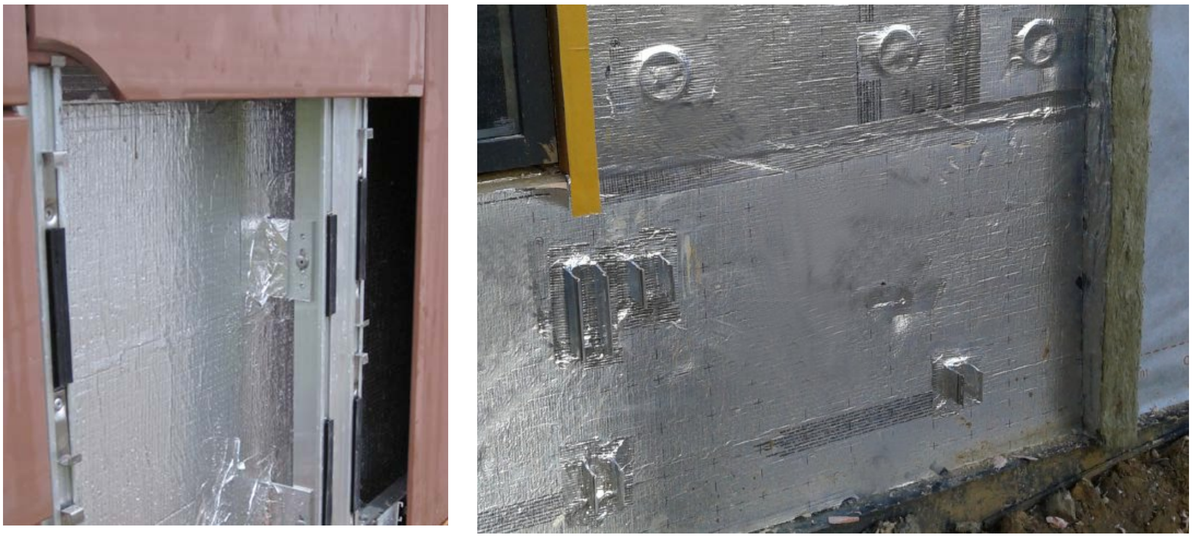


Figure 5.12 – Foil faced insulation as water barrier

5.8.2 Water barrier – EWIS

The outer face of an EWIS is conceived as being waterproof, however it should be recognised that deterioration over time may occur as a result of long term weathering; water penetration following movement particularly at interfaces; and a lack of maintenance. It is therefore sensible to employ the same approach with a render system as with a rainscreen system. For this reason, a drained cavity behind the insulation is recommended and a membrane may be provided at the back of the cavity to form a water barrier, *Figure 5.13*.

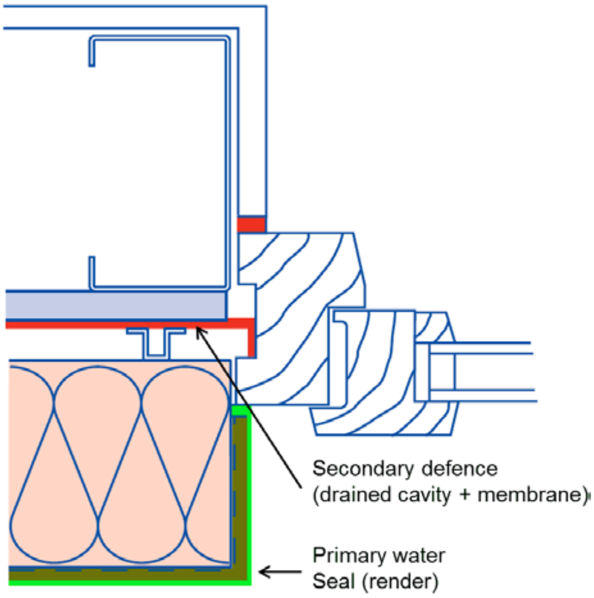


Figure 5.13 – EWIS with secondary defence against water penetration

5.8.3 Vapour control layer

Vapour control layers are provided where required to control the migration of water vapour into elements of construction vulnerable to condensation. In a UK-type climate the requirement is normally to limit the passage of vapour from within the building through the wall to a point at which condensation may occur. In warm humid climates the requirement may be to limit the passage of moisture through the wall from outside to inside.

The need for a vapour control layer will depend on:

- vapour permeability of each layer of the wall;
- temperatures within the wall;
- internal and external moisture levels;
- the effectiveness of any ventilation of the cavities within the wall.

5.8.4 Air barrier

Walls are required to be air tight to limit heat loss by mass transfer of air. Airtightness may be achieved by the wall construction adopted, may be a consequence of a membrane provided for moisture control or may require the provision of an additional membrane.

5.8.5 Appearance

Where rainscreens with open joints are used the back wall may be visible through the rainscreen joints. In such cases it may be desirable to ensure that the face of the back wall is of uniform appearance and this can be achieved by the use of a membrane. Membranes used for this purpose are normally black but other colours are available.

5.8.6 Other considerations

In addition to these functions the membrane may be required to have the following properties:

- physical robustness;
- UV resistance;
- flame retardant characteristics.

Polymeric membranes are combustible but may be formulated to give flame retardant characteristics. This is more likely to be significant for breather membranes which are located on the outer face of the insulation and may therefore affect fire spread within a rainscreen cavity.

Possible alternatives to using membranes for some of the above functions may include:

- plastered surfaces,
- foil-backed plasterboard,
- taped joints between sheathing boards.

The effectiveness of such measures will depend on the materials used, how they are installed (joints between boards for example) and how they are detailed.

5.9 Membrane location

Depending on the type and build-up of the wall, multiple membranes may have to be used to provide the air barrier, water barrier and vapour control layer. In some cases, a single membrane, appropriately positioned may perform all the required functions.

In order for any membrane to perform as intended, care must be taken to ensure that it is not damaged during installation and in use. Installation of a vapour control layer may require the material to be lapped or pierced by fixings. The materials may also become pierced as a result of damage during construction. The design should have due regard for the means of installation and the susceptibility to condensation related problems. Where required, taping or sealing of joints should be specified and precautions taken to ensure that any discontinuity or piercing of the layer by essential fixings does not compromise the performance. Where membranes pass over movement joints in the supporting structure it is necessary to ensure that the membrane also allows movement for example by creation of a tuck in the membrane.

A VCL and/or air barrier may be installed as part of the internal dry lining. This may be a separate membrane, foil-backed plasterboard or similar. In practical terms it is difficult to make a membrane at this location continuous across the building envelope. Features such as floor slabs and other penetrations will interrupt the membrane and therefore careful detailing and sealing is required in order to achieve continuity.

When assessing the risk of interstitial condensation, a representative value of the vapour resistance should be used. This should take into account any gaps or discontinuities in the membrane/foil lining. An example is given in Section 6.8.3.6.1.

A membrane may be fixed to the sheathing boards. When fixed in this location it must be securely attached which is usually achieved by the use of small staples. A sufficiently robust membrane should be used so that the staples do not cause it to tear. This is the ideal place for a membrane as it can be fixed to a flat surface which is protected. It is also more straightforward to ensure penetrations due to brackets etc. are adequately sealed. It is also the most economical.

Fixings for brackets will penetrate any membrane fixed to the sheathing boards. Constructed correctly this should not cause any significant reduction in performance as the membrane is clamped between two solid elements (the bracket and the sheathing) so any holes are effectively sealed.

Membranes in this position in a rainscreen wall will be protected by the insulation in the cavity, *Figure 5.14*. This has two benefits; firstly, the insulation will prevent the majority of water entering the cavity from reaching the membrane, and secondly it will ensure that the membrane is securely attached to the sheathing and doesn't move due to air movements in the cavity which may cause it to tear around staples/fixings etc. The mechanical fixings used to attach the insulation will also help in this regard.

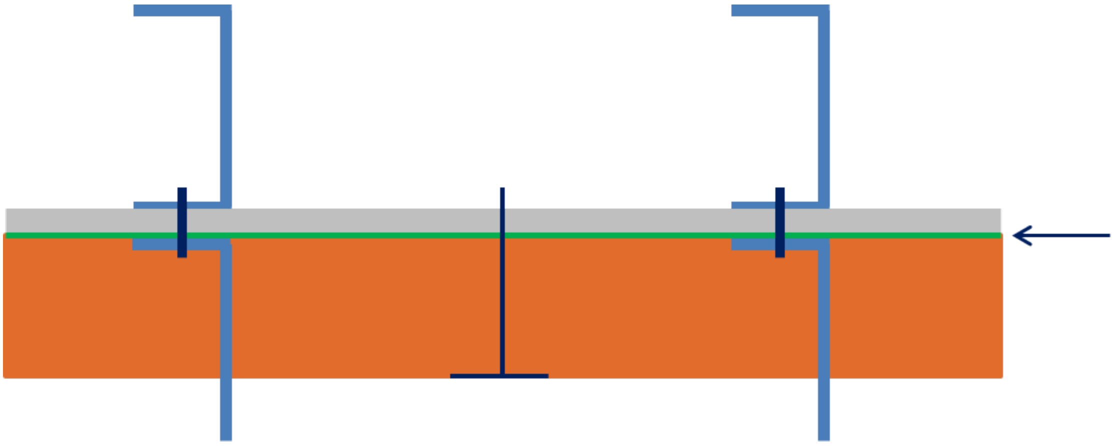


Figure 5.14 - Typical membrane position - rainscreen system

Figure 5.15 shows a likely membrane position for an EWIS that incorporates a cavity. The membrane is fixed to the sheathing boards by staples as before. Top hat sections, brackets or proprietary fixings are used to create the cavity between the insulation and the sheathing. These fixings should clamp the membrane as before.

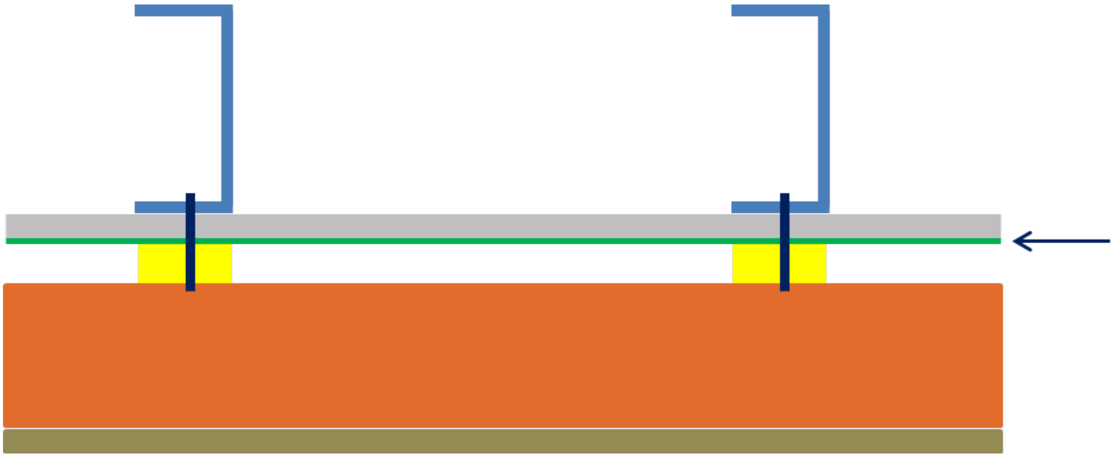


Figure 5.15 - Possible membrane position - EWIS with cavity

Due to the position of the cavity the membrane is not as protected as it is in a rainscreen wall. The cavity may be subject to variations in pressure which may cause the membrane to move. It may also be subject to greater exposure to water particularly around penetrations and openings as the insulation is not present to shield it. The cavity will however allow better drainage of water than when the membrane is in close contact with the insulation.

Figure 5.16 shows a possible membrane position in an EWIS without a cavity, where it would be subject to similar conditions to those of a rainscreen system described earlier. A membrane in this position would preclude the use of adhesive bonding for the insulation to the back wall.

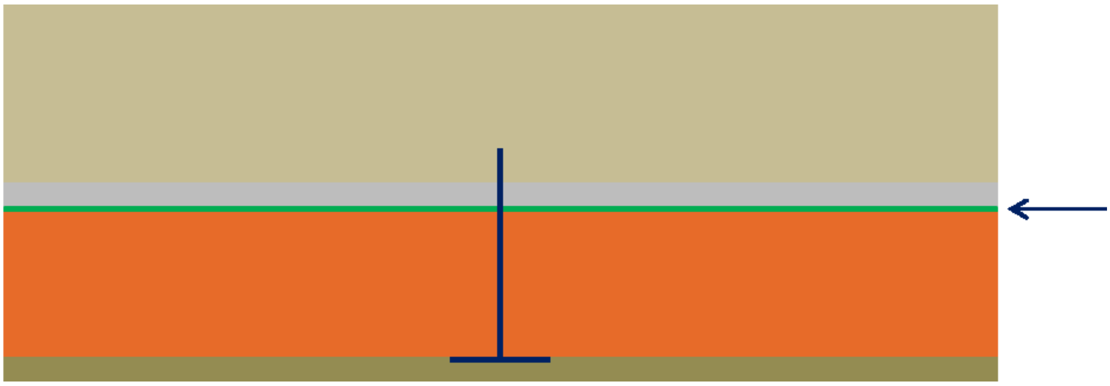


Figure 5.16 – Possible membrane position – EWIS without cavity

This document recommends that for a framed back wall a cavity is used in all cases. For a solid back wall a cavity should be incorporated, except for low-rise loadbearing walls. See Chapter 3 for further details.

For a rainscreen system the final possible membrane position is on the outer face of the insulation, *Figure 5.17*. This location is not appropriate for an EWIS as it prevents the render from bonding to the insulation. In this position the intention is to act as a water barrier, protecting the insulation and back wall from wetting. A membrane in this position is difficult to install. Brackets for the rainscreen panels will penetrate the membrane, requiring careful sealing to maintain the integrity of the membrane. There are also questions regarding the long-term performance of tape materials used in this location due to the exposure to water. It may therefore be necessary to install a further membrane behind the insulation for additional protection/to add to the robustness of the wall.

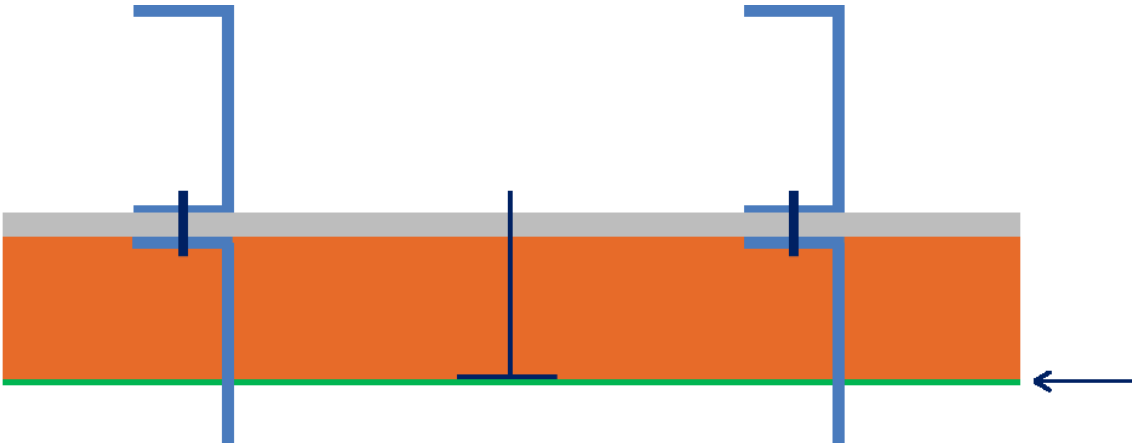


Figure 5.17 – Possible membrane position – rainscreen system

Particular care must be taken when the back wall is insulated. Insulating the back wall will change the overall temperature distribution across the wall, as shown in *Figure 5.18* below. In turn this may alter the position of the dew point temperature, and therefore the optimum position of the VCL.

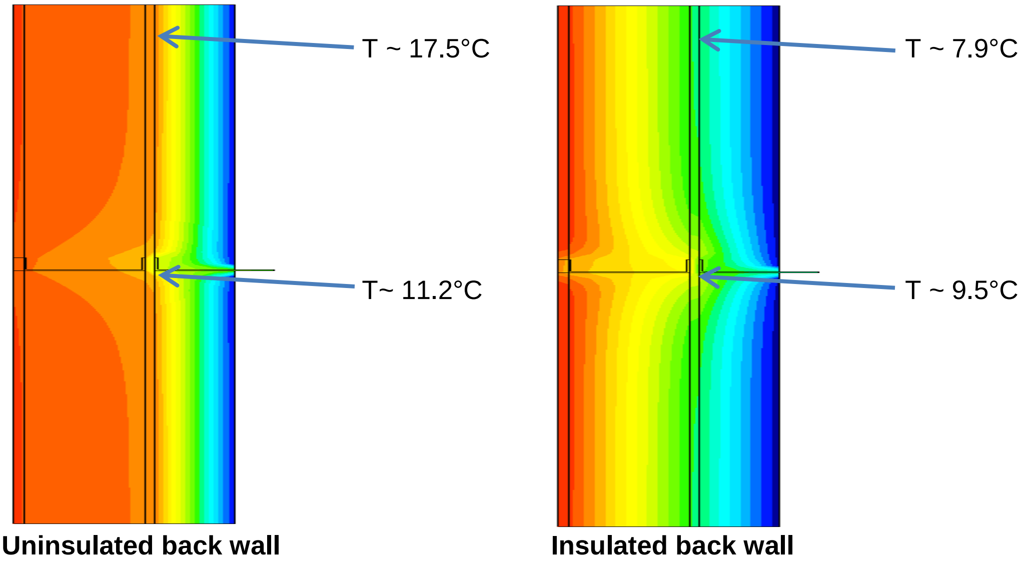


Figure 5.18 - Effect on temperature distribution caused by placing insulation in the back wall

It is important to establish the position of the dew point temperature. The dew point is the temperature at which water vapour starts to condense out of the air (the temperature at which air becomes completely saturated). Above this temperature the moisture will stay in the air.

In simple terms the dew point will be in one of two positions:

- within the rainscreen or external insulation,
- within an insulated back wall (usually a stud back wall).

Where the dew point is within the stud back wall care must be taken to ensure that any membranes on the cold side of the dew point will not trap moisture vapour diffusing through the wall as this will lead to interstitial condensation. Also in such a build-up the stud wall is potentially a zone wetted by condensate and thus all studs and associated cut ends will require protection against corrosion (for steel studs) and rot protection (for timber studs).

5.9.1 Dew point within the rainscreen/external insulation

Figure 5.19 and *Figure 5.20* below show a rainscreen and an EWIS on a stud back wall. For both systems the dew point is within the external insulation. The potential membrane positions are shown and described below.

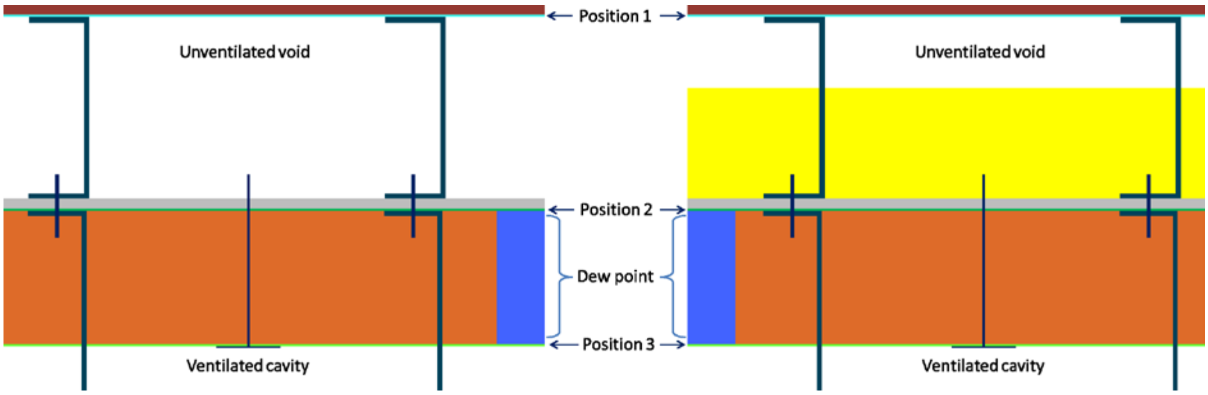


Figure 5.19 – Possible membrane positions, rainscreen, stud back wall (uninsulated (left), insulated (right)), dew point within rainscreen insulation

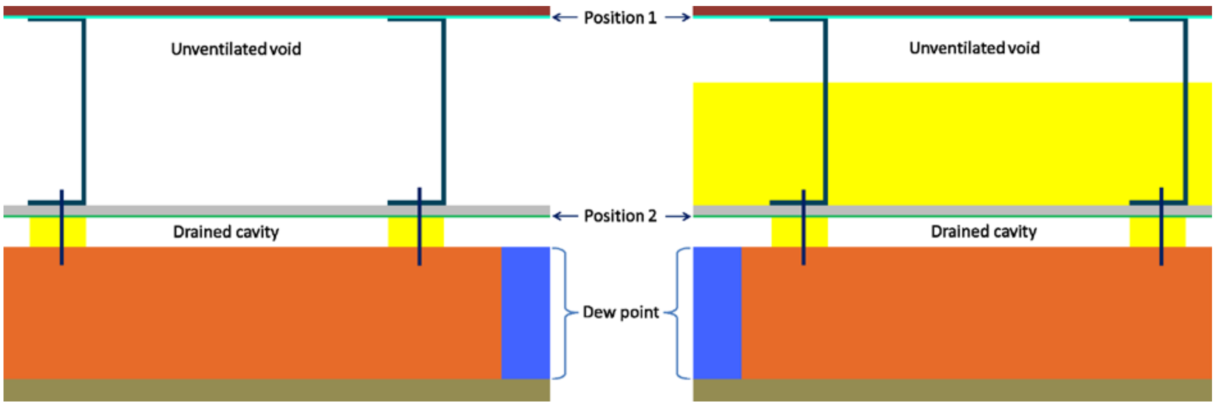


Figure 5.20 – Possible membrane positions, EWIS, stud back wall (uninsulated (left), insulated (right)), dew point within external insulation

Position 1	
Function	**Air barrier, vapour control.**
Explanation	• A VCL in this position will provide an air barrier and a vapour control layer. • Being to the warm side of the insulation layer is the optimum position in terms of minimising the risk of interstitial condensation. • Best performance will be achieved using a separate, appropriately specified membrane. • Alternatively, a foil/polyethylene sheet pre-attached to the internal lining may be used, however the continuity of this is very difficult to achieve. • A plastered surface may act as the air barrier for a masonry back wall.
Notes	• Difficult to ensure continuity of the membrane at floor slabs and other penetrations. • Sealing around service penetrations/electrical fittings is difficult. • If a membrane is used how is it fixed to resist air exfiltration? • Risk of subsequent damage due to occupants hanging pictures, attaching shelves etc. which may puncture the membrane. • Need to consider the position of the water barrier.

Position 2	
Function	**Air barrier, water barrier, vapour control.**
Explanation	• A single membrane (VCL) in this position can provide an air barrier, water barrier and a vapour control layer. • Suitable where the back wall is not insulated, or where a condensation risk analysis has been carried out showing the dew point is not within the back wall.
Notes	• Generally considered to be the easiest and most economical position in which to install a membrane. • Risk of condensation if the membrane is damaged/not installed correctly.

Position 3	**(Rainscreen only)**
Function	**Water barrier, appearance.**
Explanation	• The insulation may have to be protected from wetting. • Being to the cold side of the insulation, this layer must be water resistant and breathable. • A breather membrane may be used here to give a uniform appearance and so that the insulation is not visible through panel joints etc.
Notes	• A membrane in this position is difficult to install due to multiple bracket penetrations. • The water penetration resistance may be limited by how well penetrations are sealed. • Not essential if insulation tolerant of wetting (and a water barrier is installed elsewhere). • In an open jointed system, the effect of UV exposure on the membrane must be considered, UV resistant membranes are available. • Flame retardant membranes are available if the Building Regulations require one (generally for buildings greater than 18m high). • A vapour control layer in this position is likely to cause interstitial condensation and so should not be used.

5.9.2 Dew point within the stud back wall

Figure 5.21 below shows a rainscreen and an EWIS on a stud back wall. For both systems the dew point is within the internal insulation in the stud wall. The potential membrane positions are shown and described below

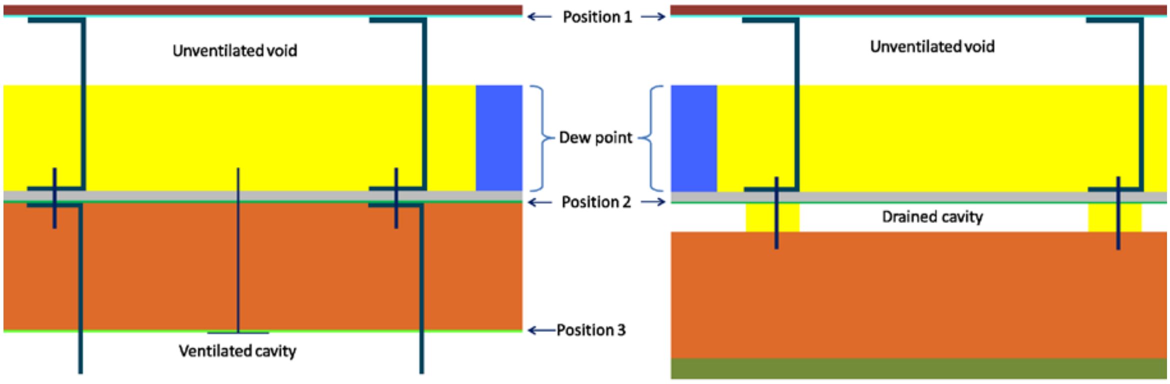


Figure 5.21 - Possible membrane positions, rainscreen (left), EWIS (right), stud back wall, dew point within back wall

Position 1	As before.
Position 2	
Function	**Air barrier, water barrier.**
Explanation	• A membrane in this position must be vapour permeable - a VCL in this position will result in interstitial condensation. • Water barrier is still required. • May be achieved using a breather membrane or by taping joints between water resistant sheathing boards.
Notes	• Generally considered to be the easiest and most economical position in which to install a membrane. • Durability of taped joints is questionable. • Additional VCL required to the warm side.
Position 3	As before.

5.10 Membrane continuity

As discussed previously, consideration must be given to other elements which will interrupt an otherwise continuous membrane.

5.10.1 Windows

Figure 5.22 shows a window sill interface with a rainscreen wall which includes brackets and a cavity barrier.

In this example there are three key areas which must be addressed in order to stop/limit the amount of water entering the wall:

- window interface (A),
- rainscreen bracket (B),
- cavity barrier (C).

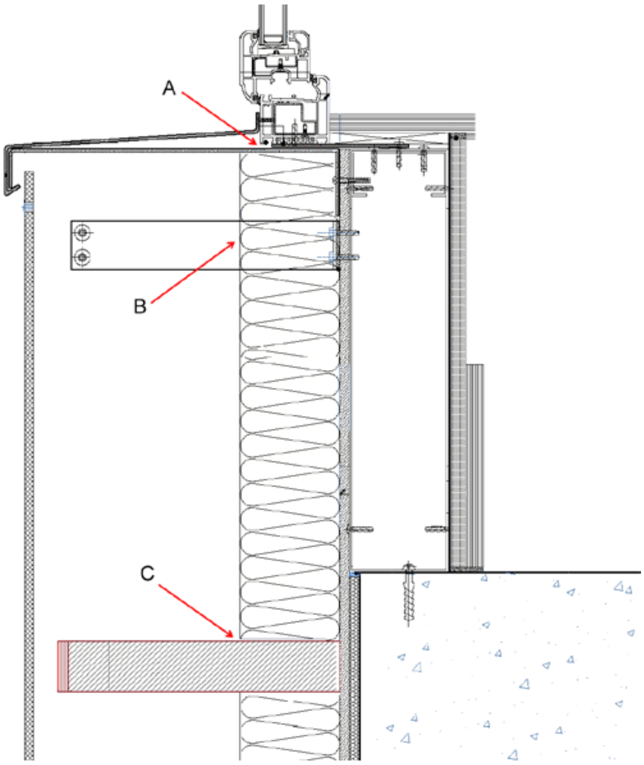


Figure 5.22 – Window sill interface with rainscreen bracket and cavity barrier

The interface between the window sill and the rainscreen below (A) presents a potential weak spot if not detailed correctly.

It is possible that water may get between the window frame and the sill pressing onto the sill support below. Ideally this support would direct water away from the wall and/or have some drainage openings to allow any water present to drain into the rainscreen cavity. Depending on the angle of the sill support water may track back into the wall.

The cavity barrier at slab level (C) will ideally slope slightly downwards, directing water running down the face of the insulation away from the back wall. However, it should be recognised that in practice the cavity barrier may be level or slope slightly upwards directing water into the wall. It is therefore necessary to construct the wall in such a way that any remaining water will be removed without causing subsequent damage.

There are two main approaches that can be taken with regard to the positioning of membranes.

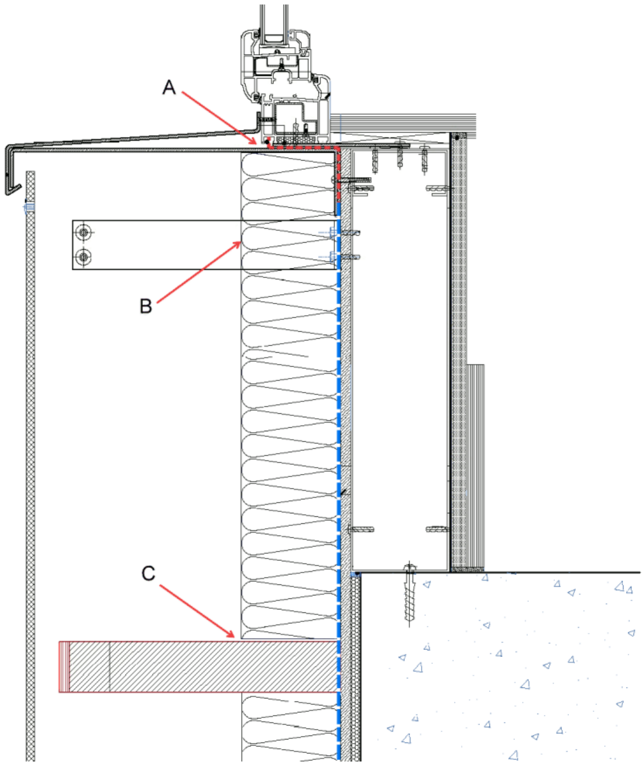


Figure 5.23 – Window sill interface with rainscreen bracket and cavity barrier – alternative configuration

Figure 5.23 shows a membrane fixed to the sheathing boards. A membrane, e.g. EPDM or similar, (red) provides the air and water seal between the window and the sheathing (*Figure 5.24*). This will prevent any water tracking back along the window sill support from getting into the back wall.

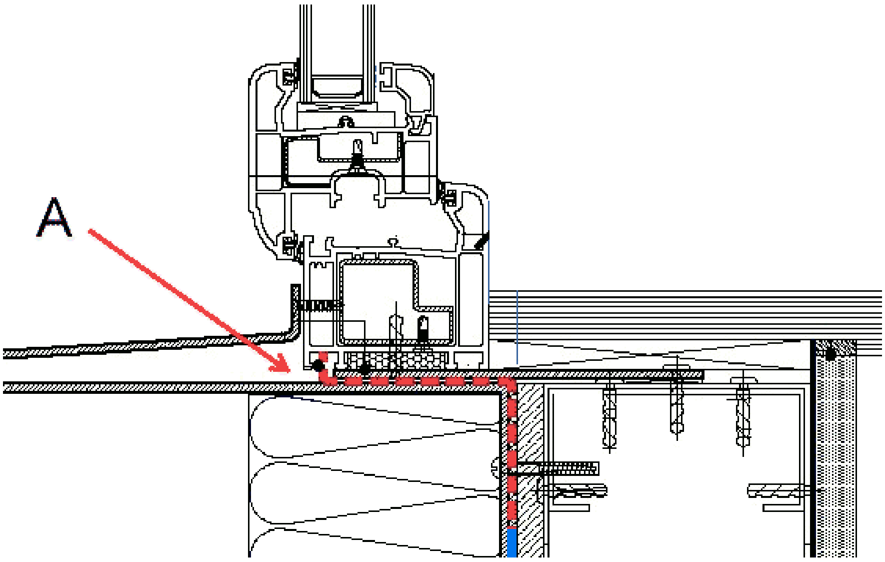


Figure 5.24 – Window sill detail with EPDM membrane (red)

An additional membrane (blue) is fixed to the sheathing boards. This membrane is continuous and is not interrupted by brackets and cavity barriers and therefore is simple to construct and should offer a reliable and robust solution. This membrane (blue) can be tucked under the membrane (red) above so that a continuous water barrier is formed on the line of the sheathing boards. If the back wall is uninsulated, or if the dew point is within the rainscreen insulation, this membrane could be a VCL and would provide the air and water barrier and vapour control layer.

An alternative membrane configuration is shown in *Figure 5.25* below. This configuration may be necessary if the insulation cannot be wetted, or if a membrane is required on the outer face of the insulation for appearance purposes.

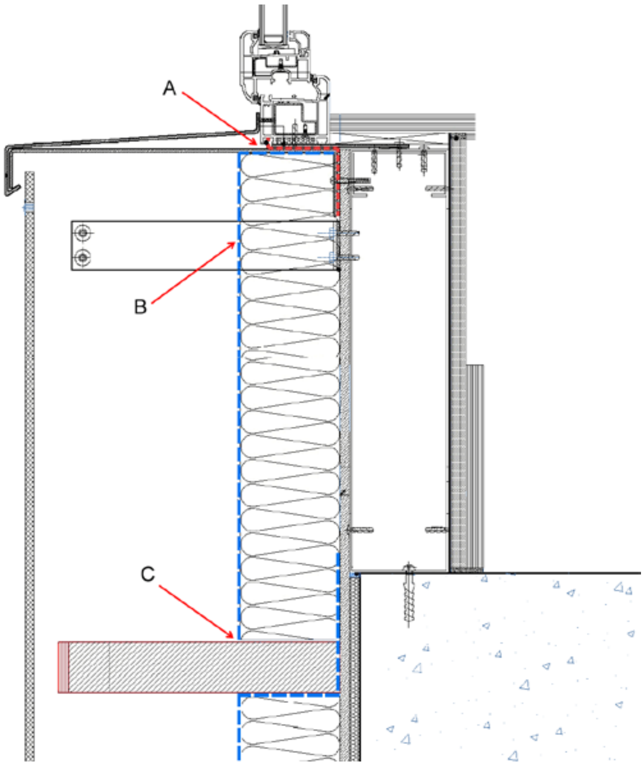


Figure 5.25 – Window sill interface with rainscreen bracket and cavity barrier

A membrane is used between the window frame and the sheathing boards as before, however as there is no continuous membrane fixed to the sheathing boards, the boards themselves are being relied upon to prevent any water present from getting into the back wall. Alternatively, an additional membrane could be fixed to the sheathing as before, however this introduces further cost, and therefore is often excluded.

A breather membrane is positioned on the outside of the rainscreen insulation. The rainscreen brackets form regular penetrations in this membrane (B). Attempting to seal these penetrations with tape is difficult and it should be assumed that water may get behind the breather membrane.

The cavity barrier also penetrates the breather membrane when in this position. For both cases the membranes should be arranged so that water passing the outer membrane is directed back out of the wall. By fitting the breather membrane behind the cavity barrier any water running down the sheathing boards should be removed from the wall at this point.

Additional membranes may be required to form the air barrier and VCL.

The performance of configuration *Figure 5.23* is likely to be superior to that in *Figure 5.25*.

When considering an interface design, it is vital to think in 3-dimensions. Whilst a continuous air barrier or VCL may be shown on a plan or section drawing, it is not always clear how that continuity will be ensured at junctions and corners.

Figure 5.26 below shows a window head, sill and jamb interface with a rainscreen on a lightweight steel-framed back wall. The water- and airtightness of the wall depends on two membranes. Firstly, a VCL is installed to the front face of the lightweight steel frame (green line), and secondly an EPDM or similar membrane fitted between the window frame and the back wall. Key to overall performance is ensuring that the membranes are correctly installed around corners, membranes are properly lapped and bonded/fixed to the substrate.

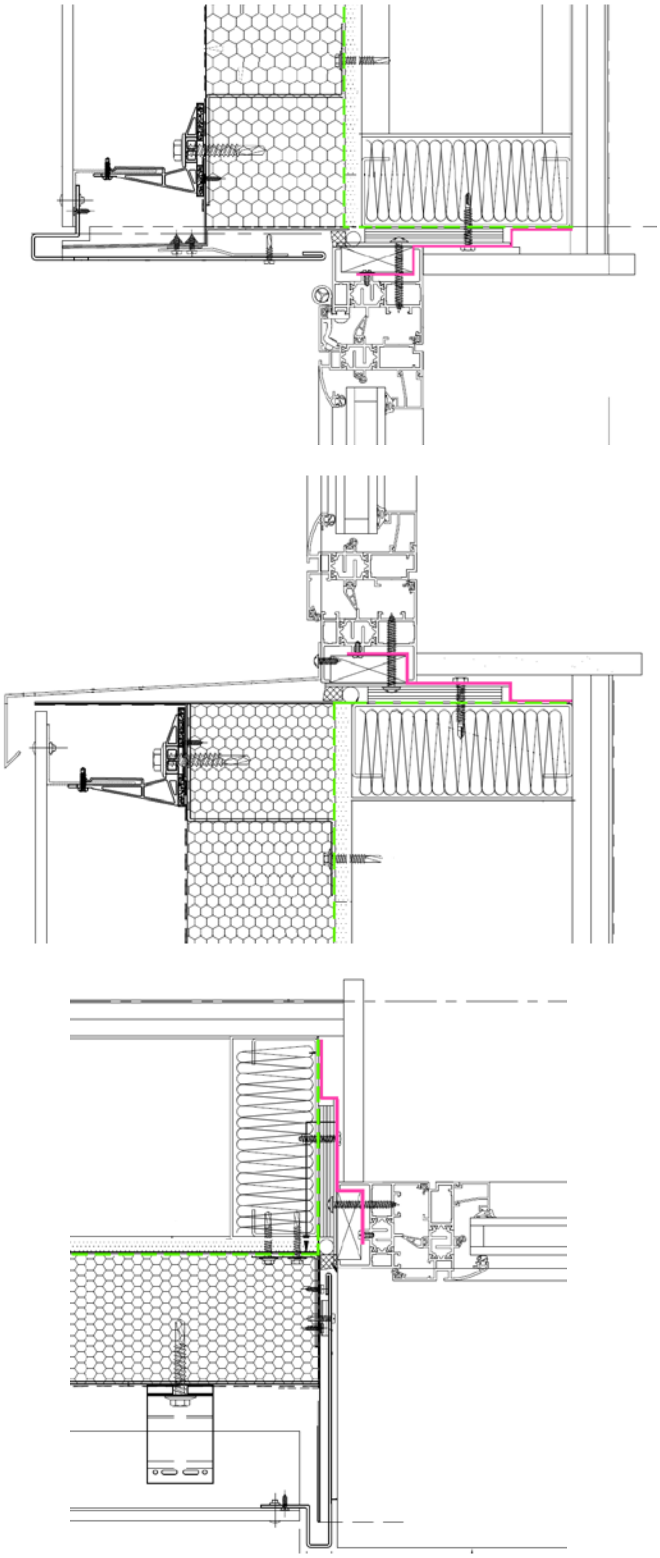


Figure 5.26 - Window head, sill and jamb interface

5.10.2 Slab edge details

Ensuring the continuity of membranes at details such as slab edges is vital. Membranes that are not continuous will result in increased air leakage, possible water penetration and a greater risk of interstitial condensation.

With a concrete frame/floor slab this is generally straightforward as the membrane can be fixed to the edge of the floor slab/sheathing running across the slab. This is shown in *Figure 5.27 and Figure 5.28.*

If there is a movement joint between the floor slab and the head of the back wall it should be ensured that the membrane can accommodate the anticipated movement. This may be achieved through the natural stretch of the material, or alternatively the membrane may require a 'tuck' in the movement joint.

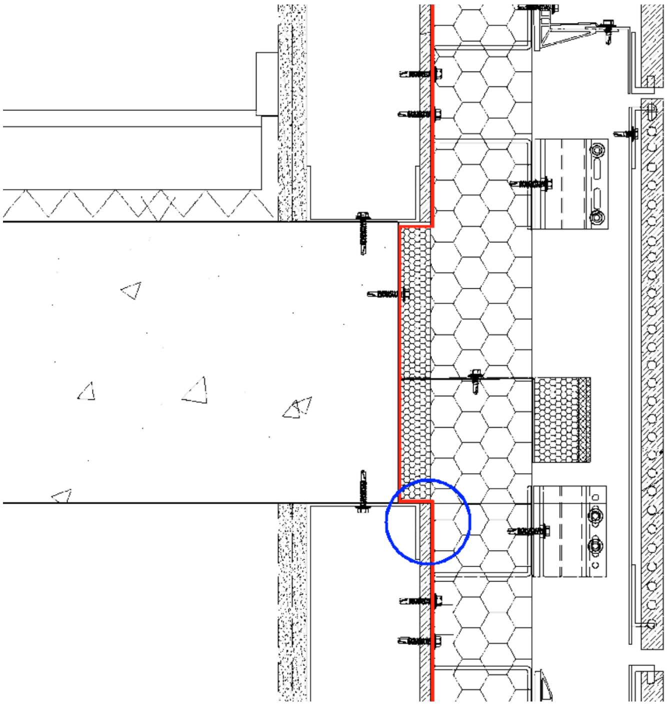


Figure 5.27 - Membrane fixed to face of concrete floor slab

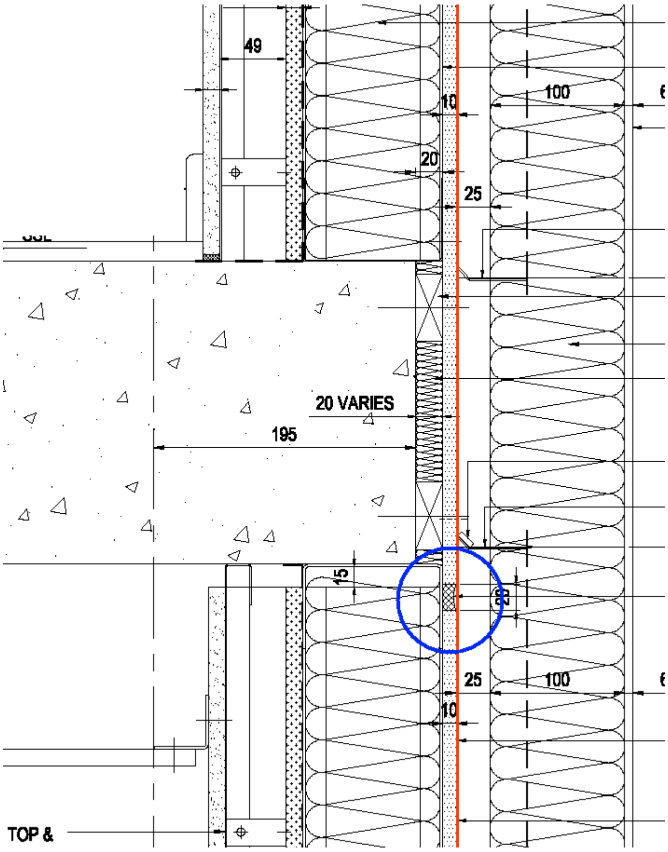


Figure 5.28 - Membrane fixed to sheathing continuous across floor slab, movement joint

Where a steel frame or composite floor deck is used the requirements for a continuous membrane can be more challenging.

Figure 5.29 shows continuous sheathing across the face of the composite floor slab to create a flat surface as before. This has required one bracket fixed to the steel edge beam and a second bracket fixed to the sheathing to allow for tolerances etc. Movement joints may be required as before.

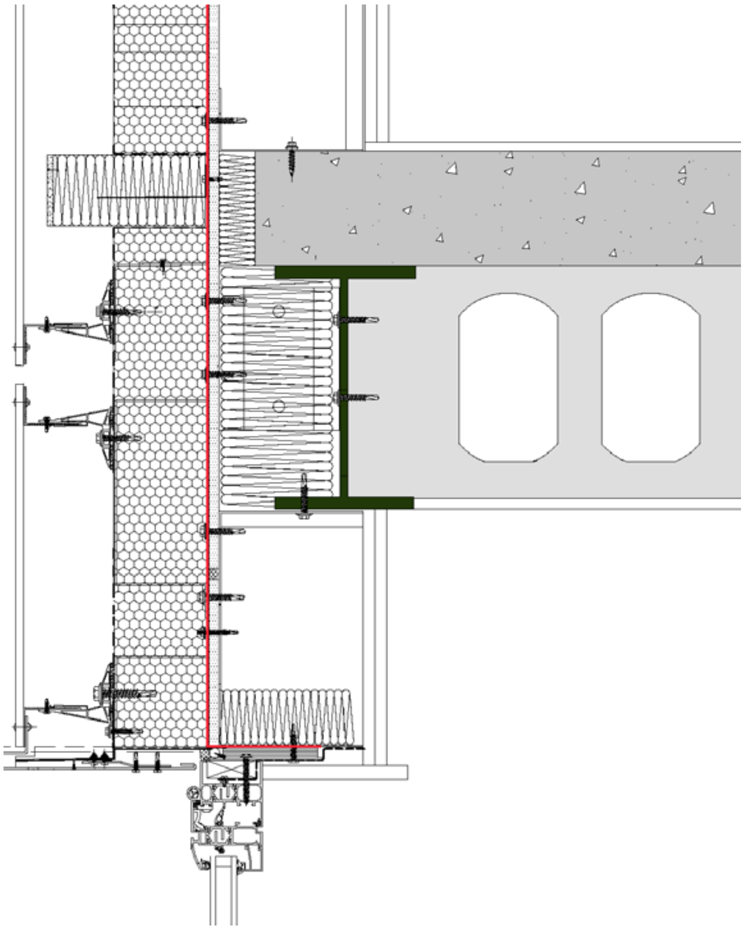


Figure 5.29 - Continuous sheathing across composite floor slab

Figure 5.30 shows an alternative approach where the sheathing is not continuous across the face of the composite floor slab. In addition to trying to fix the membrane around the slab edge and the steel edge beam, there will also be columns which will have to be dealt with, making this approach difficult to ensure continuity of the membrane.

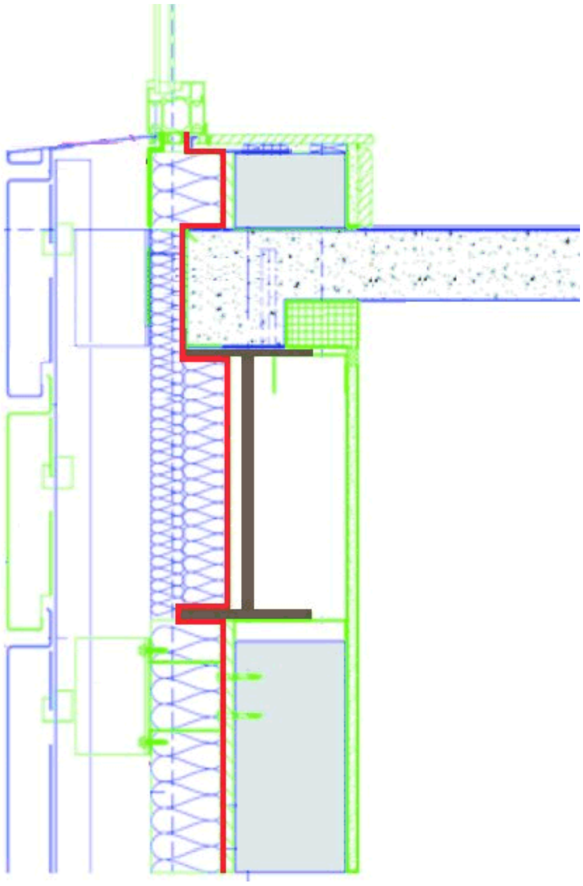


Figure 5.30 - Membrane fitted around edge beam

5.11 Other penetrations

5.11.1 Mains Services

The cavity of a rainscreen wall may be used to conceal/route services such as gas pipes and rainwater goods (downpipes etc.). When anything is placed in the cavity in this way, key considerations include sealing around cavity barriers to prevent the spread of fire within the cavity, and access for maintenance. It should be possible to inspect and maintain any pipes, drains, etc. with minimal disruption to the wall. In addition, for gas pipes there are also concerns regarding fire in the cavity and adequate ventilation in the event of a gas leak. The CWCT Standard for systemised building envelopes states that all electrical and mechanical services shall pass directly through the wall, and they shall be sealed to the air barrier.

5.11.2 Service Penetrations

Figure 5.31 shows water leaking where a flexible service duct has been fitted through the backing wall.

Figure 5.31 - Service penetration through the backing wall

The detail shown in *Figure 5.31* was destined to fail as it would be almost impossible to adequately seal around a flexible duct. A far better solution would have been to fit a rigid section of ducting which can be robustly fixed and sealed to the wall to prevent water and air leakage.

Where a ventilation duct passes through the backing wall it is vital that the fire performance of the wall is not compromised, both in terms of fire spread from the cavity into the building and vice versa. The duct should therefore be protected to the same standard as a cavity barrier. This is discussed further in Section 6.6 on fire performance.

5.11.3 Temporary works

External access is required in order to construct a built-up wall. Often this will consist of scaffolding which needs to be tied back to the building structure for safety/stability. Often this means cutting through the sheathing boards as shown in *Figure 5.32*. This will usually be done by the scaffolding contractor with little regard to the consequences for the wall.

Where the back wall has to be modified to accommodate temporary works the method should be approved by the contractor responsible for the wall together with details on how the wall will be made good on removal of the scaffolding.

Figure 5.32 - Scaffolding ties

5.11.4 Attachments

Attachments to the façade in the form of shading devices, signage, CCTV cameras etc. need careful detailing in order to maintain the integrity of the wall.

The design of any attachment should be carried out in conjunction with the wall designer to ensure:

- structural integrity of the wall and attachment;

- thermal performance/minimisation of condensation risk:
  - thermal bridging,
  - continuity of VCL;
- weathertightness.

Particular attention should be paid to projects where the wall and attachment, for example a shading device (*Figure 5.33*), are split into separate packages. There are façade contractors/suppliers who can offer integrated systems which will help to ensure a coordinated approach to the design.

Figure 5.33 - Shading devices fixed to a rainscreen wall

5.12 Refurbishment

When considering the refurbishment of an existing building there are two types of interface that must be considered:

- the interface between the built-up wall and the existing wall, for example in an overcladding situation;
- the interface between the built-up wall and any retained elements, such as windows.

When overcladding an existing wall it is vital that the existing building is properly surveyed and appraised so that a suitable interface design can be established.

Of particular concern is the condition and strength of existing concrete and masonry structures where new fixings are to be installed. Appropriate testing should be carried out to prove suitability of the existing structure for refurbishment. Reference should be made to BS 5080-1 - *Structural fixings in concrete and masonry - Method of test for tensile loading*, BS 5080-2 - *Structural fixings in concrete and masonry - Method for determination of resistance to loading in shear* and the Construction Fixings Association (CFA) Guidance note, '*Procedure for Site Testing of Construction Fixings - 2012*', when planning to test fixings on site.

The CWCT *Standard for systemised building envelopes* states that at least five per cent of all installed anchors should be tested, with a minimum of 10 for fixings into existing concrete, to ensure that the substrate is capable of carrying the new loads.

Interface detailing during renovation work can be particularly difficult due to the additional complications and constraints involved in retaining certain elements of the wall, such as windows. Window sill interfaces present a particular problem as it is likely any existing sill would not project far enough to cover the new insulation. The solution often proposed is an over-sill mechanically fixed or bonded to the existing window profile. The long term durability of such an interface may be questioned. It may also put additional load onto the external render, and if so it should be ensured that the required support can be provided. Replacement of the existing sill with a new one of the required size is likely to be a better solution.

Another potential issue with refurbishment is one of thermal bridging at window interfaces. If windows are not replaced at the same time as the walls are insulated there may not be room to insulate the window reveal. This is shown in *Figure 5.34* and *Figure 5.35* below.

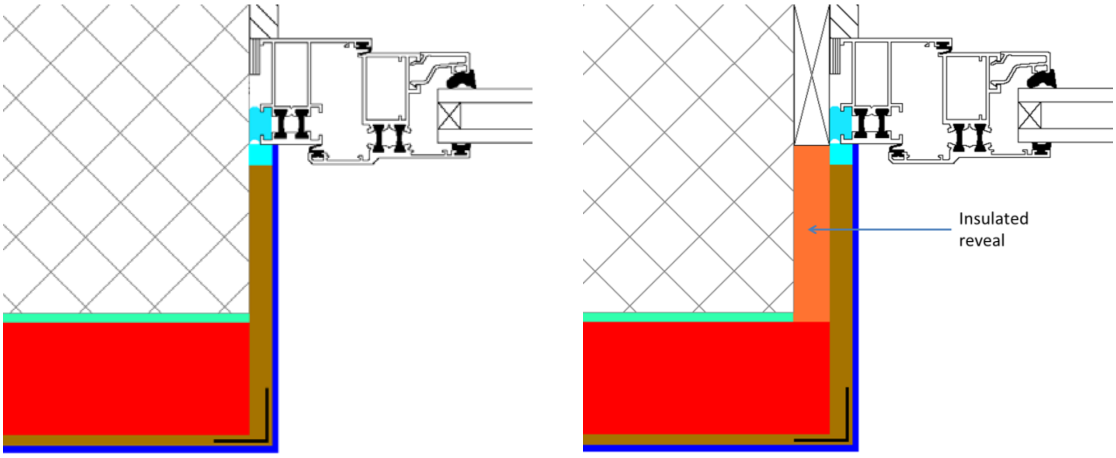


Figure 5.34 – Uninsulated (left) and insulated (right) window reveal.

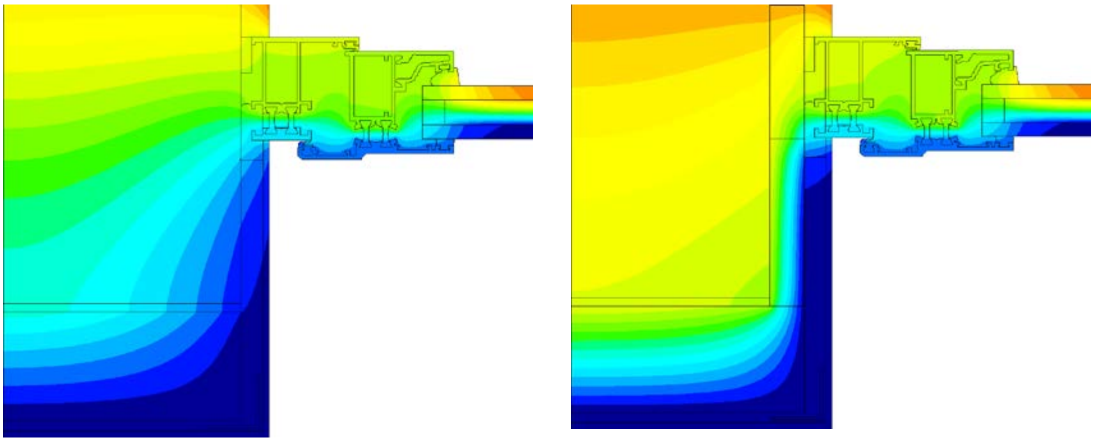


Figure 5.35 – Uninsulated (left) and insulated (right) window reveal – Temperature distribution

The left side image of *Figure 5.35* shows the temperature distribution of an uninsulated reveal. At the interface with the window the external insulation is essentially bypassed resulting in significantly cooler temperatures within the back wall which could increase the risk of interstital condensation forming.

The temperature distribution shown in the right side image of *Figure 5.35* is significantly improved. Here the insulation is continuous at the interface resulting in clearly defined warm and cold areas. The temperatures within the wall are much higher and therefore the risk of interstitial condensation is reduced.

6 SYSTEM PERFORMANCE

6.1 WATERTIGHTNESS

Walls are required to resist rain penetration to the interior of the building and to parts of the building fabric that could be adversely affected by water.

Watertightness of a rainscreen wall is achieved by the rainscreen limiting the amount of water that enters the wall and by effective removal of this water by drainage and ventilation. The amount of water passing the rainscreen may be limited by the design of the rainscreen to such an extent that any water reaching the back of the cavity does not cause significant wetting and can be removed by evaporation and drainage without causing detriment to the wall. In this case there is no requirement for a waterproof layer at the back of the cavity. In other cases, the rainscreen may allow significant amounts of water to pass and an additional water barrier is required to prevent the inward migration of water. It is common practice to have a water resisting membrane in all rainscreen walls. This often takes the form of:

- aluminium foil facing to the cavity face of insulation boards with foil tape over the board joints and around rainscreen fixing brackets. This method has the disadvantage that it is time consuming to install as all the penetrations at brackets have to be sealed. Any water and condensate that gets behind the foil is likely to be trapped within the wall;
- a breather membrane, normally located between the back wall and the insulation. If the membrane is behind the insulation it will be subject to less water than on the face of the insulation. As the breather membrane is vapour permeable, any small amounts water that does penetrate the membrane, for example at penetrations for fixings, may be able to escape by evaporation. Fixing a breather membrane on the outer face of the insulation creates difficulties with bracket penetrations for the rainscreen rails;
- a waterproof membrane, commonly EPDM or reinforced virgin polyethylene, between the back wall and the insulation, where the dew point is external to the back wall. This can provide a very efficient solution (being air, water and vapour tight) but care is required in detailing and installation to ensure that penetrations are watertight to ensure that water does not become trapped in-board of the membrane.
- a backing wall construction that is waterproof such as metal faced composite insulated panels. If relying on blockwork construction for the inner leaf, care needs to be taken in the detailed design and with workmanship to ensure it has the required watertightness.

An EWIS may be designed to achieve watertightness using one of the following approaches in increasing robustness;

- Face sealed in which the render, in combination with sealant at interfaces, provides the only resistance to water penetration
- Face sealed with drained joints at discontinuities in the render
- Dual barrier with drained joints. The dual barrier requires a second waterproof layer to limit inward migration of moisture but does not provide a drainage layer to remove significant amounts of liquid water
- Drained systems which employ a drainage layer or cavity in addition to a second water barrier, as required by the NHBC for framed back walls.

Recommendations for drainage/cavities are discussed in Chapter 3.

6.1.1 Building Regulations

Building Regulations require walls to adequately protect the building and people who use them from harmful effects caused by precipitation including wind driven rain. Guidance on meeting this requirement throughout the various regions of the UK is given in the following documents:

- England: Approved Document C – *Site preparation and resistance to contaminants and moisture;*

- Northern Ireland: Technical Booklet C – *Site preparation and resistance to contaminants and moisture;*
- Scotland: Technical Handbook - Section 3 – *Environment;*
- Wales: Approved Document C – *Site preparation and resistance to contaminants and moisture.*

These documents provide limited guidance in relation to rainscreen walls or walls with external insulation on a framed backing wall.

Approved Document C and Technical Booklet C state that any framed external wall will meet the requirements of the Regulations if external cladding is provided which is separated from the insulation or sheathing by a vented and drained cavity and a vapour permeable water resisting layer is provided on the inside face of the cavity. The Technical Handbook for Scotland requires a ventilated cavity where impermeable cladding is used and a vented cavity for porous cladding such as tile hanging.

These recommendations do not take account of the increased levels of insulation now required in walls as the examples shown assume that sufficient insulation can be provided between the studs of a framed back wall. This means that any insulation is protected from water by a membrane on the face of the back wall and that any water reaching the face of such a membrane can drain freely. To satisfy current thermal insulation requirements it is normally necessary to provide insulation within the rainscreen cavity. The insulation then either needs to be resistant to intermittent wetting or protected by a water resisting membrane.

Approved Document C and Technical Booklet C accept the use of rendered external insulation applied directly to a solid back wall without the need for a drained cavity. Where an impervious cladding, which would include a render finish on external insulation, is supported by a back wall containing timber components, a ventilated cavity is required between the back wall and the cladding. The use of external insulation on a steel framed back wall is not specifically addressed but is presumably considered acceptable without a ventilated cavity. The Scottish Technical Handbook does not give recommendations for rendered external insulation with a framed back wall.

6.1.2 Specification

Walls must comply with the Building Regulations but the specification may include additional requirements which may be in the form of a performance requirement or prescriptive requirements relating to the form of construction.

The CWCT *Standard for systemised building envelopes* provides for watertightness to be specified in terms of the performance of a test specimen. A test specimen would normally be a section of the wall two storeys high built as the front face of a pressure chamber such that water can be sprayed on the outer face of the specimen in conjunction with an air pressure difference across the wall. For a rainscreen system a static pressure difference across the wall does not replicate the air movements through the rainscreen and a dynamic aero engine test is required. This will direct a jet of turbulent air against the outer face of the rainscreen and will cause some water to be blown through the joints. The equivalent test pressure should be specified; in the CWCT *Standard for systemised building envelopes* the recommended test pressure is related to the site wind pressure as shown in *Table 6.1.1.*

Wind pressure (Pa)	Watertightness test pressure (Pa)
Up to 1200	300
1201 to 1600	450
1601 to 2400	600
Over 2400	0.25 x wind pressure

Table 6.1.1 - Recommended watertightness test pressures from CWCT Standard

Specifying performance in this way is a practical approach for major projects where a project test can be carried out. It is less satisfactory for walls constructed using standard components where the cost of a project test would be prohibitive. A test on a sample panel of a plain rainscreen carried out by a system supplier may bear little relationship to the performance of a rainscreen wall with windows and other interfaces. In such circumstances it may be necessary to rely on an engineering assessment of the proposed method of construction in conjunction with evidence of past performance and site testing of details.

The performance of windows to be included in a built up wall should be specified. Windows may be tested as part of a test on the complete wall but more commonly the windows will be manufactured from standard systems that have been previously tested and classified in accordance with BS EN 14351-1 - *Windows and doors - Product standard, performance characteristics - Windows and external pedestrian doorsets without resistance to fire and/or smoke leakage characteristics*.

The watertightness of windows complying with BS EN 14351-1 is assessed in accordance with BS EN 1027- *Windows and doors – Watertightness -Test method* and classified in accordance with BS EN 12208 - *Windows and doors – Watertightness - Classification*. The classification depends on the air pressure difference across the specimen during the test and the direction of water spray. For water spray method A, the axis of the spray nozzles is 24º below horizontal and for method B it is 84º below horizontal. Method B is suitable for locations where the window is in a more protected location. The possible test pressure classes are given in
Table 6.1.2.

Pressure class	Test pressure (Pa)
1	0
2	50
3	100
4	150
5	200
6	250
7	300
8	450
9	600
Exxx[1]	>600

1. Above class 9 the performance is classed E followed by the maximum pressure achieved e.g. E850 for a maximum pressure of 800 Pa.

Table 6.1.2 - Watertightness classes for windows from BS EN 12208

BS 6375-1 - *Performance of windows and doors - Classification for weathertightness and guidance on selection and specification* recommends using spray method A with test pressures increasing with wind pressure as shown in *Table 6.1.3*.

Wind pressure (Pa)	Test pressure (Pa)
Up to 1200	100
1201 to 2000	200
Over 2000	300

Table 6.1.3 - Recommended watertightness classes from BS 6375-1

Where the wind load does not exceed 800Pa BS 6375-1 states that doors may be acceptable with a performance less than 100Pa depending on their exposure to rain and the nature of their location.

If using spray method A, the performance classes will be comparable with CWCT performance classes of the same pressure. There is no provision for dynamic testing of windows. The test pressure classes recommended in BS 6375-1 are lower than those recommended in the CWCT *Standard for systemised building envelopes* and specifying windows and doors with higher levels of performance will reduce the risk of water leakage.

In addition to specifying the performance of windows, prescriptive requirements may also be given, most commonly a requirement for drained and ventilated frames.

Specifications for rainscreen walls should make reference to compliance with the CWCT *Standard for systemised building envelopes*. This Standard includes prescriptive requirements in relation to the cavity width and any pressure equalisation of the cavity. These requirements are given in Section 3. Similar requirements are also given in the NHBC Standards Chapter 6.9 – *Curtain walling and cladding*.

Specifications should require the provision of a cavity in walls with external insulation. The NHBC requires a drained cavity at least 15mm wide where external insulation is used on a framed back wall. Where a timber framed back wall is used, the cavity is required to be ventilated. A ventilated cavity on the inside of the insulation will affect its thermal performance.

Specifications may require the use of wall systems with independent certification to demonstrate watertightness. This is more appropriate for external insulation which is generally supplied as a complete system with recommended interface details. With rainscreens, the performance is heavily dependent on interfaces at windows and abutments with other forms of construction which are unlikely to be represented by tests on the basic rainscreen system. Furthermore, Agrément certificates may assume the rainscreen to be applied to a water tight back wall, which may not be the case.

Site watertightness tests may also be specified both to check workmanship of the installed wall and to check interface details. The principal test methods that may be used are the spray bar test and the hose test. Both methods of test are described in the CWCT Standard for systemised building envelopes and the spray bar test is also covered by BS EN 13051:2001 - *Curtain walling – Watertightness - Site test*. For a rainscreen wall, site watertightness tests are likely to be most appropriate for checking interface details particularly around windows and may be carried out before the installation of the rainscreen panels. The hose test would be appropriate for sealant joints and EPDM membranes bonded to non-porous materials but is likely to be too severe to apply to breather membranes. The spray bar test would be more appropriate for details where breather membranes are used. Site watertightness tests should be carried out before installation of internal linings so that the source of any water ingress can be located.

6.1.3 Assessment

Assessment of watertightness may be carried out in the following ways:

- a project laboratory test on a typical sample of the complete wall including windows and their interfaces with the surrounding wall;

- a system test on the rainscreen in conjunction with an engineering assessment of details such as provision of secondary membranes and interface details;
- a system test on the back wall construction;
- an engineering assessment of the system based on a history of satisfactory performance in service;
- independent certification of external insulation in conjunction with an engineering assessment of interface details.

6.1.3.1 Project laboratory test

A project laboratory test may be required for any built up wall but is probably more common for rainscreen walls. The cost of a project test means that it is only appropriate for large contracts.

With most rainscreen walls some water will be blown across the rainscreen cavity during the test and will wet the face of any material at the back of the cavity. Generally, the greater the height of the cavity the greater the degree of wetting. The extent of water penetration may depend on the width of the air gap, thickness of insulation, presence of cavity barriers, fixings used for the insulation, presence and method of retaining water resistant layers and detailing around penetrations including windows.

For a project test these details will be known and should be replicated in the test specimen. When a project test is carried out it will normally be part of a comprehensive test regime including air permeability, wind resistance and possibly impact tests.

To enable the extent of water penetration to be assessed, viewing ports are normally provided in the back wall so that the extent of water within the cavity can be seen. At the end of the test it is necessary to dismantle sections of the wall to assess the extent of water penetration. This should include removal of sections of any water resisting membranes as water may be trapped between membranes and the sheathing of the back wall.

Prior to testing a rainscreen wall for watertightness, the permissible extent of water penetration through the wall should be established. Water should not penetrate to the inside face of the wall. The presence of water within the rainscreen cavity is acceptable provided that it is adequately drained. Whether other materials in the wall are allowed to be wetted will depend on the nature of the materials used and should be established for a particular wall prior to test.

6.1.3.2 Rainscreen system test

This is generally less satisfactory than a project test. System tests may be carried out on a rainscreen system on a representative back wall but the system may then be used with different back wall constructions, different insulation arrangements and different cavity widths. Window interface details will also vary. The test specimen should replicate the worst arrangement likely to be used. This will generally be;

- minimum width of air gap;
- minimum thickness of insulation;
- inclusion of horizontal fire barrier.

However, it is not generally possible to replicate window interface details in a system test as these vary from project to project.

Any use of a system test will require engineering judgement to assess its validity and the watertightness of details not covered by the test.

6.1.3.3 System test on back wall

In some cases, the back wall is constructed from a fully watertight system such as metal faced composite insulated panels. In such cases the back wall can be tested for watertightness without the presence of the rainscreen. Any fixings for the rainscreen that might compromise the watertightness of the back wall should be present. A system test on the back wall should include a window opening but the detailing of the window interface may vary from project to project. The window interface will then need to be assessed and this will be on the basis of engineering judgement possibly supplemented by site watertightness tests.

6.1.3.4 Engineering assessment

Many rainscreen walls are constructed based on application of general principles without any testing. It is assumed that the rainscreen will allow some water to enter the rainscreen cavity and a secondary water resisting layer is provided to prevent further inward migration. The effectiveness of a water resisting layer will depend on detailing of joints and the ability to install it without damage.

The water resisting layer may be a breather membrane or a more substantial membrane such as EPDM. Joints in the water resisting membrane should be lapped and sealed either by bonding or with an appropriate tape. Membranes should also be sealed to adjacent construction at interfaces. Inevitably there will be penetrations in the water resisting layer as a result of fixings for the layer itself, for insulation, or for rainscreen support brackets.

6.1.3.5 Independent certification of EWIS

Most EWIS have some form of independent third party certification, either from the British Board of Agrément or in the form of an ETA. Agrément certificates give an assessment of fitness for purpose based on an evaluation of the product which will include appropriate testing. The scope of the Agrément certificate may be limited, for example Agrément certificates for EWIS may be limited to applications on a solid backing wall. Any use of a system outside the scope of its certification requires a careful engineering assessment.

An ETA requires an assessment in accordance with ETAG 004 – *Guideline for European Technical Approval of external thermal insulation composite systems with rendering.* Tests for watertightness of rendered external insulation systems are included in ETAG 004. These tests are very different from the tests set out in the CWCT Standard in which the sample is subjected to water spray in combination with simulated wind pressure. The tests in ETAG 004 subject the sample to extreme temperatures and water spray but without simulated wind pressure.

Strictly ETAG 004 only applies to external insulation systems supported on a solid back wall but in the absence of alternative guidance, systems are used on framed back walls based on assessment in accordance with ETAG 004. Systems supported on a framed back wall may be subject to greater movement which may increase the risk of cracking the render. The requirement to provide a cavity within the system may also affect behaviour as the system may be more vulnerable to impact damage. Another limitation of the test procedure in ETAG 004 is the size of the test specimen which has minimum dimensions of 2 m high and 2.5 m long with a minimum area of 6 m^2. Whilst the test regime subjects the sample to extremes of temperature in addition to water, the small size specimen will be less prone to cracking than a larger specimen. A sample less than one storey height is unlikely to include a movement joint.

Joints in external insulation systems may be sealed with proprietary jointing strips with a membrane seal, wet applied sealants or impregnated foam strips. When using sealants, it is necessary to check compatibility with the insulation material and the render will generally have to return over the edge of the insulation board to give a sufficient bond area. Use of drained joints is likely to give better long term performance and is recommended in all cases.

SCI has proposed a ranking system for external insulation systems that can be related to the exposure conditions (SCI Publication P343, Insulated Render Systems Used With Light Steel Framing). This is a more sophisticated version of a system developed in Canada as a result of problems of water penetration (Ontario Association of Architects, Rain Penetration Control Practice Guide). The Exposure classification is based on the exposure zones given in Approved Document C. The basic zones apply to buildings up to 4 storeys and taller buildings are moved into the next higher class. Alternatively, the exposure can be evaluated in terms of the driving rain index as described in BS 8104:1992 - *Code of practice for assessing exposure of walls to wind-driven rain*.

In the SCI guidance, performance is assessed both for the basic system and for joint details. The ranking for the system gives points for third party certification, presence of a cavity or drainage layer and waterproofing of the back wall.

CWCT recommends that external insulation systems used in built up walls should have independent certification, be installed with a drained cavity (with the exception of low-rise loadbearing solid walls – see Chapter 3, and that joints should be drained.

6.1.4 Workmanship

In all cases the quality of installation must be checked to ensure that the required performance is achieved. This will require a programme of inspection which may be supplemented by site tests at appropriate stages of the installation of the wall.

6.2 AIRTIGHTNESS

Airtightness has become an important factor in the control of heat loss from buildings. Air leakage can also cause draughts which cause discomfort to building occupants. Airtightness requires the identification of an air barrier which must be made continuous over the whole building envelope. This requires particular attention at interfaces between different forms of construction.

6.2.1 Building Regulations

The Building Regulations throughout the UK (Approved Document L for England and Wales, Section 6 of the Technical Handbook for Scotland and Technical Booklet F for Northern Ireland) require the completed building to be tested to demonstrate airtightness. Guidance on meeting this requirement throughout the various regions of the UK is given in the following sets of documents:

- England:
  - Approved Document L1A – *Conservation of fuel and power in new dwellings* (AD L1A – E),
  - Approved Document L1B – *Conservation of fuel and power in existing dwellings* (AD L1A – E),
  - Approved Document L2A – *Conservation of fuel and power in new buildings other than dwellings* (AD L1A – E),
  - Approved Document L2B – *Conservation of fuel and power in existing buildings other than dwellings* (AD L1A – E):
- Northern Ireland:
  - Technical Booklet F1 – *Conservation of fuel and power in dwellings* (TB F1),
  - Technical Booklet F2 – *Conservation of fuel and power in buildings other than dwellings* (TB F2);
- Scotland:
  - Technical Handbook – Domestic – Section 6 – *Energy* (TH D6),
  - Technical Handbook – Non-Domestic – Section 6 – *Energy* (TH ND6);
- Wales:
  - Approved Document L1A – *Conservation of fuel and power. New dwellings* (AD L1A – W),
  - Approved Document L1B – *Conservation of fuel and power. Existing dwellings* (AD L1A – W),
  - Approved Document L2A – *Conservation of fuel and power. New buildings other than dwellings* (AD L1A – W),
  - Approved Document L2B – *Conservation of fuel and power. Existing buildings other than dwellings* (AD L1A – W).

Measurement of airtightness is required to be carried out in accordance with the following standards published by The Air Tightness Testing & Measurement Association (ATTMA), see www.attma.org:

- Technical Standard L1 – *Measuring air permeability of building envelopes (dwellings)*
- Technical Standard L2 – *Measuring air permeability of building envelopes (non-dwellings)*

6.2.2 Specification

All buildings are required to be airtight and testing of the completed building is normally required to demonstrate compliance with Building Regulations. The requirements for the test are set out in the Building Regulations but the permissible rate of air leakage must be specified as this will depend on how the building has been designed to control energy use. Normally the required air leakage rate is between 5 and 10 $m^3/hr/m^2$ at a pressure difference of 50 Pa but lower values are increasingly being specified. Air leakage of the whole building determined in this way depends on all elements of the building envelope and the interfaces between them.

In addition to the general requirement relating to the building as a whole, airtightness requirements may be specified for individual elements of the building envelope. The CWCT *Standard for* *systemised building envelopes* describes procedures for testing the airtightness of building envelopes. This requires a representative sample of the wall to be constructed on a pressure box at a laboratory. There are three standard test pressures of 300, 450 and 600Pa and the specifier needs to state the required test pressure. A higher test pressure gives a more airtight wall but even a test pressure of 300Pa would limit the leakage rate at 50Pa to less than $1m^3/hr/m^2$. This procedure is appropriate for curtain walling where the main concern is air leakage through gasket joints which can be reproduced on a test sample. It may be employed for built up walls on major projects where the cost of a test can be justified but built up walls are often assessed on the basis of robust details. For built up walls, the airtight backing wall is often constructed as infill between floor slabs and the interfaces between the back wall and floor slabs and around windows would need to be replicated in a test sample.

The performance of windows for use within a built up wall should be specified. Windows complying with BS EN 14351-1 are classified in four standard classes. BS 6375-1 which gives guidance on specification of windows recommends Class 2 for most applications but the leakage rate at 50 Pa permitted for Class 2 windows is over $15m^3/hr/m^2$. Class 3 and 4 windows give better performance; Class 4 windows are available with a leakage rate of less than $1m^3/hr/m^2$ at 50 Pa. The leakage for the window does not include any leakage at interfaces with the surrounding construction including the interface between the window frame and the sill.

6.2.3 Construction

In a built up wall, airtightness depends on the back wall, the windows and the interfaces between the windows and the back wall and between the back wall and adjoining parts of the building envelope. In many cases the back wall is constructed as infill between the floors and the seal between the back wall and the floors will also be important.

In the design of a built up wall, the air barrier needs to be identified and needs to be made continuous at interfaces between different forms of construction. This may require the use of membranes and sealants as described in Chapter 4.

For a masonry wall, the air barrier will normally be the plaster or dry lining on the inside face of the wall.

For a stud wall, the air barrier may be sheathing boards on the cavity face of the studs. In this case the joints between the boards must be sealed. The internal lining to the back wall may also form an air barrier. The air barrier will be subject to wind load in both positive and negative directions and the air barrier needs to be supported so that it can resist the resulting forces. The loads acting on the air barrier are considered in Section 0. The air barrier needs to be continuous at movement joints without restricting movement. Any penetrations through the air barrier for services, balcony supports etc. should be sealed.

To give some idea of the sealing requirements, the ATTMA Standards give the following relationship:

$$A = Q_{50}/5.57$$

Where:

- A is the area of openings in m^2 per square m of building envelope
- Q_{50} is the air leakage rate at a pressure difference of 50Pa in $m^3/s/m^2$

This is only an approximate guide as the leakage rate through an opening will depend on the shape of the leakage path. For an air leakage rate of $10m^3/hr/m^2$ the openings in the building envelope would need to be limited to about $500mm^2$ per m^2 of envelope. If the air barrier were to be composed of sheathing boards 1m wide the joints would have to be limited to 0.5mm wide, the boards would have to be perfectly airtight and there would be no allowance for any air leakage through joints in the transverse direction or at opening joints around windows and doors or other defects. It follows that all regular joints in the air barrier must be sealed.

6.3 STRUCTURAL PERFORMANCE

Built-up walls are required to carry all of the loads applied to them safely and to remain serviceable. They are normally non-load bearing and are designed by the building envelope contractor.

Built-up walls may also be the primary load bearing structure or be required to at least contribute to the strength and stiffness of the primary load bearing structure.

In low to medium rise building the back wall may be load-bearing. This may be in the form of:

- blockwork or masonry;
- cold formed steel framing;
- timber framing;
- timber SIPs.

The back wall is then required to carry vertical compressive loads to resist the self-weight of the building and shear loads to resist wind load and seismic action. In this case the project structural engineer will be responsible for checking the structural stability and deflections of the back wall. It is important that the project structural engineer understands, and takes account of the additional loads applied directly to the back wall.

Where a framed back wall is used, the loads from a rainscreen cladding should be applied directly to the framing members, rather than via the sheathing boards. Depending on the spacings of the panels and studs, additional horizontal components (‘top hats’) may be required to transfer the loads to the framing members.

6.3.1 Principles

The structural components in the wall should be designed so that the wall is:

- safe;
- serviceable;
- durable;
- buildable.

Structural safety is ensured by defining the loads applied to the wall and checking that these do not exceed the load capacity of the wall. It is also necessary to check that no additional loads are generated by:

- restraining movement of the cladding components;
- movement of the supports.

The condition where the applied loads are equal to the load capacity of the wall is known as the ultimate limit state (ULS).

Serviceability is achieved by limiting the deflections that occur within the wall. Deflections are limited to:

- give building occupants confidence that the wall is safe;
- ensure that infill, windows and doors, sheathing, lining and so on are correctly supported;
- ensure that infill, sheathing, lining and interfaces do not fail due to excessive movement.

The condition where the actual deflections are equal to the allowable deflections is known as the serviceability limit state (SLS).

Durability is achieved by the appropriate selection of materials and ensuring that reversals of load do not cause fatigue failure.

Buildability is attained by using structural components and other elements of an appropriate size and using appropriate jointing techniques.

6.3.2 Specification

Whole wall specification requires:

- definition of loads;
- allowable deflections;
- movement of the primary structure.

Loads may be defined by:

- magnitude and position;
- building location;
- environmental conditions.

Wind load and snow load may be specified by magnitude or the location of the building may be given, leaving the specialist contractor to calculate loads in accordance with the appropriate wind code. Note that the magnitude of the wind load on the building envelope depends on the dimension of the component. Wind loads used by the structural engineer may be different from those required for the cladding design, for example wind loads on the building envelope will be greater than on the structural frame. It is also necessary to allow for any dominant openings when assessing the wind load on the building envelope. The building envelope may be zoned with different wind load specified for each zone.

Barrier loads, access loads and impact loads will depend on the way in which the building is to be occupied and used. The Specifier should give magnitudes of load or classes of performance as appropriate.

The Specifier should give details of any known fixtures or attachments that will be supported by the building envelope and which may transfer wind load and snow load to the building envelope.

The Specifier should give details of any fit-out that will transfer loads to the building envelope including cupboards, wash hand basins and so forth.

Allowable deflections should be given in the specification. Default values for allowable deflections are given in various Standards and Building Codes but lower values may be required depending on the materials to be used. Of particular concern is the effect of deflections on internal finishes and external renders.

Movement of the primary structure is a consideration in the design of the back wall of a built-up wall. A report from the structural engineer detailing movements of the primary structure should be provided.

6.3.3 Basis of structural assessment

It is important not only to know the type and magnitude of the loads applied directly to a built-up wall but also to know where they are applied. This is fundamental to the design and structural assessment of the different components and layers within the wall.

The applied loads may be classified as shown in *Table 6.3.1*:

Permanent	Variable loads	Dynamic loads
Self-weight Transferred loads*	Wind load Snow load Transferred loads* Barrier loads Access loads	Impact

**Transferred loads arise from self-weight, wind load, snow load and access loads on signage, shading devices and internal fixtures.*

Table 6.3.1 - Classification of loads

6.3.3.1 Load paths

Loads may be applied to the cladding or back wall. For each load there is a load path that ensures it is transferred to the primary load bearing structure.

Figure 6.3.1 shows a typical case where wind load and self-weight are transferred from the rainscreen panels to support rails to the framed back wall. For clarity a single panel is shown, which is hung from the support rail. The support rail is fixed to the framed back wall via a central bracket which carries wind load and self-weight and further brackets which only carry wind load. Clearly all components of the wall and the brackets have to be capable of carrying the loads applied to them.

It is not always apparent where the load is applied and the load path for each is discussed below.

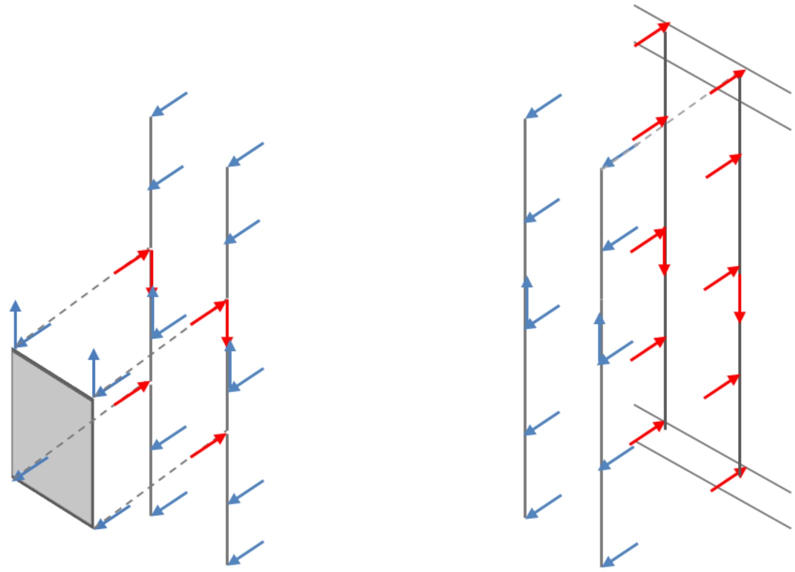


Figure 6.3.1 - Example of a load path through a built-up wall

6.3.3.1.1 Wind load

There will be an external wind pressure and an internal wind pressure due to air permeability of the building envelope and any dominant openings. Wind load acts on any layer across which a pressure difference occurs. Wind load is reversible; an increase in pressure on the outer face causes a positive wind load and a decrease in pressure on the outer face causes a negative wind load.

The rainscreen always experiences a wind load which is transferred through the support rails and brackets to the back wall. If there is sheathing on a framed back wall it will experience wind load. If there is no sheathing or the sheathing is air permeable the lining will experience wind load. Any wind load on sheathing and/or an air barrier will be transferred to the framing members of the back wall. All windows, doors and infill in Juliet balconies will experience wind loading which is transferred through the fixings to the framing members/studs. An external insulation and render will experience wind load and may separate from the wall under a negative wind load.

6.3.3.1.2 Snow load

Snow may accumulate on ledges and external fitments. It will be transferred to the back wall through other components that may include a rainscreen, support rails and brackets.

6.3.3.1.3 Occupancy loads

Horizontal loads may arise from occupants leaning against the inner surface of the wall or from them leaning against a window or the barrier of a Juliet balcony.

Vertical loads may arise from occupants sitting or standing on barriers, ledges or internal fixtures.

In the case of windows or barriers the loads on the window, balcony rail or other barrier should be transferred directly to the back wall. The window fixings or fixings for a handrail have to be sufficiently strong to transfer the barrier load to the back wall.

In other cases, the barrier load is carried by the back wall. If the back wall is of framed construction the lining must carry the occupancy loads and transfer them to the framing system.

6.3.3.1.4 Access loads

Access loads arise from maintenance operations and will be applied to the surface layers of the wall. Any fitments attached to the wall may also be prone to access loads. With normal storey heights access loads are only applied to the external surface. The rainscreen panels or render have to be strong enough to withstand the access loads. Loads on a rainscreen will be transferred through any of the brackets, support rails, or to the back wall depending on the construction. Loads on a render will be transferred to the insulation and to the back wall.

6.3.3.1.5 Self-weight

Every component will have a self-weight acting through its centroid. The weight of a rainscreen has to be transferred through the support rails, brackets and back wall depending on the construction. Note that the self-weight of a component acts through its centroid the position of which will depend on tolerances and the as constructed dimensions.

6.3.3.1.6 Permanent fixtures, additional components and services

Applied loads arise from anything supported by the wall. On the external face they include but are not limited to canopies, shading devices, Juliet balconies, signage and CCTV. On the internal face they include but are not limited to cupboards, shelving, viewing screens and other elements of fit-out.

Balconies larger than Juliet balconies that are intended to be accessed by the building occupants should be supported directly from the primary structure. Structural components passing through the wall should not contact the wall when they deflect under load. Any contact will transfer unintended loads into the building envelope.

External fitments and accessories may be connected to the rainscreen panels, support rails, sheathing, framing or back wall. The method of attachment will depend on the exact construction of the wall and the magnitude of the loads. The loads transferred from external fitments and accessories are easily determined and may be taken in to the structural calculations. They are as follows:

- self-weight;

- wind load;
- snow load;
- access load.

Internal fit out and accessories may be supported by the floor slab. Alternatively, they will be supported from the back wall or the internal lining in which case they may transfer loads to the lining or directly to the framing.

6.3.4 Loads

All loads are defined as separate characteristic loads, sometimes referred to as unfactored loads. Characteristic loads for the UK are defined as described below:

6.3.4.1 Wind load

Wind loads are calculated by reference to:

- BS EN 1991-1-4: *Eurocode 1. Actions on structures. General actions. Wind actions;*
- NA to BS EN 1991-1-4: *UK National Annex to Eurocode 1. Actions on structures. General actions. Wind actions*;
- PD 6688-1-4: *Background information to the National Annex to BS EN 1991-1-4 and additional guidance;*
- CWCT *Standard for systemised building envelopes.*

Wind load depends on geographical location, ground orography and surrounding buildings. BS EN 1991-1-4 gives rules for the calculation of the basic wind velocity (v_b) and this has to be evaluated for each project taking account of its location. The basic wind velocity is converted to a basic velocity pressure q_b. This is modified to take account of exposure and height above ground giving the peak velocity pressure q_p.

The actual pressure on the external surface of an element of the building envelope will depend on the shape of the building; taking these into account an external pressure coefficient C_{pe} can be determined. The pressure on the internal surface will depend on the relative permeability of each façade of the building and any dominant openings in the building envelope; taking these into account an internal pressure coefficient C_{pi} can be determined. Knowing the peak velocity pressure and the pressure coefficients it is possible to calculate the pressure on the external and internal surfaces of a sealed building envelope.

Note that the external pressure will vary across a façade and that the façade may be divided into zones of building envelope designed to resist the greatest pressure anywhere within the zone. Note also that the pressure on an element of cladding will vary depending on the wind direction. The design criteria for a zone of cladding should be the greatest positive pressure anywhere in the zone and the greatest negative pressure anywhere in the zone, taking account of all wind directions. Negative pressures are often greater than positive pressures.

For a window, door or curtain wall the net pressure acting on the element is the difference between the external and internal pressures.

For a ventilated cavity wall, as shown in *Figure 6.3.2*, it is desirable to know the value of C_{pc} in order to calculate the pressure in the cavity. The actual pressures in a ventilated cavity will depend on:

- permeability of the outer skin;
- the relative permeability of the two skins (openings in the outer skin);
- the cavity volume (distance between the skins);
- rigidity of the skins;
- perimeter leakage;
- whether or not the cavity is divided into compartments.

These factors determine whether a cavity is drained-and-ventilated or pressure-equalised. Measures to ensure that the cavity is pressure equalised are given in section 3.2.4.2. Whether drained and ventilated or pressure equalised, vertical cavity barriers should be provided at the corners of the building.

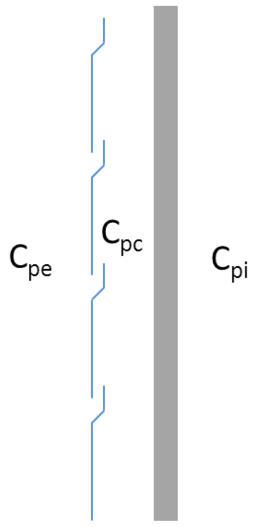


Figure 6.3.2 - Cavity wind pressures

Guidance on cavity pressures available in CWCT *Standard for systemised building envelopes* has been common practice in the UK. It distinguishes between pressure-equalised and simply drained-and-ventilated walls based on Canadian research. Taking the values of C_{pc} assumed in CWCT *Standard for systemised building envelopes* gives the pressures on the rainscreen and air barrier shown in *Table 6.3.2*.

	Drained-and-ventilated	Pressure-equalised*
Rainscreen	$q_p \times C_{pe}$	$0.67 \times q_p \times C_{pe}$
Air barrier	$q_p \times (C_{pe}-C_{pi})$	$q_p \times (C_{pe}-C_{pi})$
Windows and doors	$q_p \times (C_{pe}-C_{pi})$	

** Pressure equalisation is defined in Chapter 3*

Table 6.3.2 - Pressures assumed on each layer from CWCT

BS EN 1994-1-4 gives guidance on cavity pressures. It distinguishes only between permeable and impermeable layers but assumes different pressure coefficients (C_{pc}) for negative and positive conditions. Taking the values of C_{pc} assumed in BS EN 1991-1-4 gives the pressures on the rainscreen and air barrier shown in *Table 6.3.3*. Note that it is necessary to construct the wall as described in EN 1991-1-4 with vertical cavity barriers at the corners.

	Positive wind pressure	Negative wind pressure
Rainscreen	$0.67 \times q_p \times C_{pe}$	$0.33 \times q_p \times C_{pe}$
Air barrier	$q \times (C_{pe}-C_{pi})$	$q \times (C_{pe}-C_{pi})$
Windows and doors	$q_p \times (C_{pe}-C_{pi})$	

Table 6.3.3 – Pressures assumed on each layer from BS EN 1991-1-4

The pressures given in *Table 6.3.2* should be used. CFD studies by Zammit have shown that the coefficient of 0.33 given in BS EN 1991-1-4 is far too low.

The values in *Table 6.3.2* are based on conservative assumptions. More exact values may be obtained by testing or calculation for a particular configuration of rainscreen panels, cavity (including insulation) and air barrier but due allowance must be made for construction tolerances.

For a framed back wall where both a sheathing board and an internal lining are used then either might be the effective air barrier depending on the relative permeability and stiffness of each. BS EN 1991-1-4 gives incomplete guidance on the pressures acting on each of two impermeable layers. Based on the information given in CWCT *Standard for systemised building envelopes* and BS EN 1991-1-4 assuming both the sheathing and lining are impermeable the pressures in *Table 6.3.4* may be assumed. Note that q x C_{pi} may be a low pressure and a higher value may be appropriate.

	Sheathing more rigid		Lining more rigid	
	D&V	PE	D&V	PE
Rainscreen	q_p x C_{pe}	0.67 x q_p x C_{pe}	q_p x C_{pe}	0.67 x q_p x C_{pe}
Sheathing	q_p x (C_{pe} – C_{pi})	q_p x (C_{pe} – C_{pi})	q_p x C_{pe}	q_p x C_{pe}
Lining	q_p x C_{pi}	q_p x C_{pi}	q_p x (C_{pe} – C_{pi})	q_p x (C_{pe} – C_{pi})

Table 6.3.4 - Net pressures on layers assuming cavity pressures from CWCT

The requirement for the sheathing to be impermeable will probably be met if the sheathing boards are close fitting to each other or there is a common seal/support such that the permeability (μ) is less than 0.1%.

Wind load can only act in one place at any instant, hence when designing the back wall the external wind load can either act directly on the back wall or on the rainscreen/external insulation, with the wind load transferred to the back wall at the fixing points.

6.3.4.2 Snow load

Snow loads are calculated by reference to:

- BS EN 1991-1-3: *Eurocode 1. Actions on structures. General actions. Snow loads;*
- NA to BS EN 1991-3:*UK National Annex to Eurocode 1. Actions on structures. General actions. Snow loads*

6.3.4.3 Occupancy loads

Occupancy loads arise from people pushing against the wall or interacting with fittings and fixtures.

Horizontal occupancy loads (barrier loads) are calculated by reference to:

- BS EN 1991-1-1: *Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings;*
- NA to BS EN 1991-1-1: *UK National Annex to Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings;*
- PD 6688-1-1: *Recommendations for the design of structures to BS EN 1991-1-1;*
- CWCT *Standard for Systemised Building Envelopes.*

Vertical occupancy loads are defined in:

- BS 5234-2: *Partitions (including matching linings). Specification for performance requirements for strength and robustness including methods of test;*
- PD 6688-1-1: *Recommendations for the design of structures to BS EN 1991-1-1;*
- CWCT *Standard for Systemised Building Envelopes.*

CWCT *Standard for systemised building envelopes* and PD 6688-1-1 require a vertical load capacity of 1000 N and this may be applied to internal fixtures such as shelves and washbasins. BS 5234-2 requires a load of 1500 N at an eccentricity of 350 mm. It is advisable to assume a vertical load of 1500 N at eccentricity 350 mm for internal fixtures and 1000 N for narrower ledges.

6.3.4.4 Access loads

Access loads are calculated by reference to:

- CWCT *Standard for Systemised Building Envelopes*
- CWCT Technical Note 96

6.3.4.5 Self-weight

Self-weight load may be calculated knowing the weight of components and materials. Guidance on the density of materials is given in:

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

6.3.4.6 Transferred loads

Signage and shading devices give rise to both permanent loads and variable loads that may be included in the structural assessment of a wall. If full details of these devices are known the loads may be calculated; otherwise a structural check is required prior to installation of such devices. Notional loads may be included at the early design stage.

Permanent transferred loads are due to the self-weight of the devices. Variable transferred loads may be caused by wind load, snow load or access loads on the devices.

Internal fixtures give rise to both permanent loads and variable loads. If these are known, they may be included in the structural assessment. Very often the fit-out is not under the control of the wall contractor and actions by the occupant are clearly beyond the control of the wall contractor.

Permanent transferred loads are due to the self-weight of the fixtures. Variable transferred loads will be occupancy loads.

Guidance on a general allowance for loads due to internal fixtures is given in BS 5234-2 (*Table 6.3.5*). No guidance is given on the number or position of fixtures as the Standard considers only a single panel and not a whole wall.

In addition to the loads transferred to the wall it is necessary to resist pull-out from the internal lining. BS 5234-2 contains test procedures for evaluating the local strength of the lining.

Fixture	Direction	Load	Eccentricity
Wall cupboards	Vertical	2000 – 4000 N	300 mm
Wash basins*	Vertical	500 – 1500 N	350 mm
Lightweight anchorages	Horizontal	100 N	
Lightweight anchorages	Vertical	250 N	16 mm

** Includes an element of occupancy load*

Table 6.3.5 - Loads applied to internal surface

Balconies are normally part of the primary structure constructed by projecting the floor through the building envelope. Movement joints should be incorporated in the construction to prevent contact between the balcony platform and the building envelope to avoid the inadvertent transfer of load.

6.3.5 Load cases

The loads acting on the building envelope are not all present all of the time and they may occur in different combinations. There is also uncertainty about the loads. Although design loads are specified in codes there is a possibility, and therefore a probability, that they will be exceeded. For this reason, factors (γ_f) are applied to the loads. Commonly called factors of safety they are actually factors describing the risk of exceeding the design load.

Characteristic loads are factored to give a load with an acceptably low probability of being exceeded. Load factors for the Ultimate Limit State are larger because the consequences of excessive load are a safety concern. Load factors for the Serviceability State are lower, typically one. However, care is required to check that excessive serviceability loads do not cause components to come into contact with each other and inadvertently transfer load. Load factors for use in the UK are defined in the National Annex to BS EN 1990: *Eurocode - Basis of structural design* are shown in *Table 6.3.6*:

Load type	Ultimate Limit State	Serviceability Limit State
Variable Load	1.50	1.0
Permanent Load (unfavourable)	1.35	1.0
Permanent Load (favourable)	1.0	1.0

Table 6.3.6 - Load factors (γ_f)

6.3.5.1 Load combinations

The designer is required to consider all realistic combinations of load. For building envelopes it may be considered that:

- self-weight load is always present;
- wind load and access loads do not occur at the same time;
- that the full wind load and snow load do not act at the same time;
- that the full wind load and the full occupancy loads do not act simultaneously.

Combination of wind load and snow load – the building envelope should withstand snow load + 0.6 wind load and 0.6 snow load + wind load.

Combination of wind load and occupancy load – for dwellings and offices the greater of occupancy load or wind load for places of assembly (ULS) wind + 0.5 * occupancy or 0.5 * wind + occupancy and (SLS) greater of wind load and occupancy.

Resistance to impact is determined by test, not by calculation. When considering the possible load combinations, impact loads are assumed to act separately from other loads.

* The factors above are taken from NA to BS EN 1990; note that CWCT Technical Update 14 applies a factor of 0.6.

6.3.5.2 Ultimate limit state (ULS)

This requires the wall to have adequate resistance to meet the safety requirement. This is achieved by limiting the stresses in the framing members and other components so that tensile, compressive or buckling failure is only caused by loads that are unlikely to be exceeded in practice.

The factored loads are combined to give the load cases. The following load combinations are considered:

Dead
Dead + access
Dead + wind
Dead + occupancy
Dead + wind + 0.5* snow
Dead + snow + 0.5* wind

* The factors above are taken from NA to BS EN 1990; note that CWCT Technical Update 14 applies a factor of 0.6.

And for places where people congregate:

Dead + wind + 0.5 occupancy
Dead + occupancy + 0.5 wind

For each load case the resistance of the wall/component is calculated and compared with the loads applied.

6.3.5.3 Serviceability limit state (SLS)

This requires adequate stiffness to meet the deflection requirements.

The unfactored loads are combined to give the following load cases:

Dead
Dead + access
Dead + wind
Dead + occupancy
Dead + wind + 0.5* snow
Dead + snow + 0.5* wind

* The factors above are taken from NA to BS EN 1990; note that CWCT Technical Update 14 applies a factor of 0.6.

For each load case the deflections of each framing member and all other components are calculated and compared with the allowable deflections.

6.3.5.4 Allowable deflections

Allowable deflections are set to give occupants confidence in the integrity of the structure and to limit failure of materials attached to the structure. allowable deflections for framing members are given in CWCT *Standard for systemised building envelopes* however these cannot be directly applied to built-up walls.

6.3.5.4.1 Rainscreen

In a rainscreen, deflections of the panels, rails and back wall/internal lining should be limited.

Deflection of a rainscreen panel has the most significant visual effect on a built-up wall. The overall deflection will be a combination of deflection of the panels, rails/brackets and back wall. The limits below are from the CWCT *Standard for systemised building envelopes:*

Aluminium, glass and steel	Span/90
Stone and similar brittle materials	Span/360 or 3mm whichever is the lesser

A panel manufacturer may set more restrictive limits. A Specifier may relax these limits but should be aware that components should not come into unintentional contact and the cavity width should be maintained.

Deflection of the support rails should be limited to ensure that unnecessary stresses are not induced in the rainscreen panels. This will depend on the panel material and the fixing between the panel and the rail. Metal panels/panels fixed at four points are unlikely to cause problems. Brittle materials fixed at multiple points are more likely fail if deflection of the rail is excessive.

Deflection of the back wall is limited to minimise cracking of the internal lining/finish. Allowable deflection is normally taken as follows:

Plaste*r and similar brittle finishes*	height/360
Plasterboard	height/250

A panel manufacturer may set more restrictive limits. A Specifier may relax these limits.

6.3.5.4.2 EWIS

Deflections should be limited to minimise cracking of the render and internal linings.

The back wall of an EWIS should be compatible/designed in conjunction with the render system. If the back wall is designed to limited deflections to the values given in Section 6.3.5.4.1, this will usually be sufficient for the external render. Individual systems may have specific limits, and advice from manufacturers should be sought.

6.4 ROBUSTNESS

As well as taking into account the structural performance requirements indicated in Section 0 a built up wall should also be designed to be sufficiently robust. Robustness may be ensured by giving appropriate consideration to the following:

- impact loads;
- ability to repair;
- low cycle fatigue;
- progressive collapse;
- minimum load requirement.

6.4.1 Impact

CWCT Technical Note No, 75 – *Impact performance on building envelopes: guidance on specification* provides guidance on the specification of impact performance of walls for a range of conditions appropriate for the UK. Impact damage may be caused by accidental contact or by malicious act. Building envelopes should remain safe when subjected to expected levels of impact. Any damage caused by impact should be commensurate with the level of impact. Materials should be selected taking account of initial cost and whole life repair costs.

6.4.2 Serviceability impact

Following a serviceability impact test, there should be no loss of performance. Damage of an aesthetic nature such as indentations on metal panels may be acceptable depending on the severity of the damage, the nature of the material and location of use. Failure of components under serviceability impacts may be acceptable where the components are readily replaceable. Where materials may require replacement following impact, the acceptability depends both on the ease of replacement and the ease of obtaining replacement materials several years after construction.

Where it is impractical to use materials that can withstand serviceability impacts without damage, the loss of performance can be mitigated. For example, brittle materials may be reinforced with a mesh backing to prevent cracks opening up so that they remain in place.

6.4.3 Safety impact

The building envelope may be subject to more severe accidental impacts which it is unreasonable to resist without damage but where the consequences for the safety of those in and around the building must be considered. Safety considerations include:

- ensuring that the structural stability of the building or parts of the building are not compromised;
- ensuring that the wall is not penetrated by the impact presenting a risk to people inside the building;
- ensuring that people outside the building are not put at risk from falling debris;
- ensuring that the failure mode of the cladding does not create risks to a person impacting the surface disproportionate to the impact.

The third of these requirements is normally the most relevant. Failure of cladding panels will rarely affect structural stability of components other than the panels themselves and even if a cladding panel is penetrated by the impact, the back wall will normally prevent risk to people inside the building. The fourth requirement may be applicable with some cladding materials that produce sharp edges on failure.

6.4.4 Impacts in normal building use

Impact by people may arise from falls, trips or people being pushed against the building envelope; these are known as soft impacts and are generally limited to areas within approximately 1.5m of the adjacent ground or floor. Above this level, maintenance activities may cause soft body impact particularly when rope access or cradles are used.

Impact by objects such as shopping trolleys and other moving manually operated hard objects can cause large localised impact loads. Where there is a risk of such moving objects being able to impact the envelope and cause significant damage, a barrier may be used to prevent impact. Impacts are limited to areas within approximately 1.5m of the adjacent ground or floor. Smaller impacts from thrown objects can occur at higher levels.

Impact by furniture against the inner face of the building envelope may cause damage. The impact energy is limited by the ability of an individual to impart energy to the relatively heavy furniture. It is normally assumed that meeting the requirements of a soft impact safety test will give adequate robustness. BS 5234-2 - *Partitions (including matching linings) - Specification for performance requirements for strength and robustness including methods of test* gives guidance on impact requirements for internal partitions which would also be applicable to the internal face of an external wall.

Malicious behavior will potentially cause damage. Where there is a high risk of vandalism, impact resistance has to be considered on a project-by-project basis. An alternative approach to increasing resistance against impact loads is to provide additional security. Availability of materials that can be used to cause damage, such as loose stones, can also be reduced. If increased resistance to impact is required, it may be advantageous to use a different wall construction at ground level and other affected areas. For example, a brick or block wall at ground level with rainscreen panels/EWIS above.

Several organisations including the Home Office, local crime prevention office, the 'secured by design' website (http://www.securedbydesign.com/) and specialist consultants can also provide guidance.

Maintenance and repair activities may cause impact loads. For vertical surfaces, impacts may occur due to ladders being placed against the wall, handling of scaffold poles, use of mobile elevating work platforms, cradles and rope access. Impacts from permanent cradles will normally be reduced by use of suitable buffers. Specifiers can require that cradles are designed to limit the severity of potential impacts to the values given in *Table 6.4.1* and *Table 6.4.4* below.

Impacts from other forms of access equipment are more dependent on the care taken by the operators and no specific guidance on impact loads to be expected is available. The risk of injury from fractured material falling during maintenance work can be controlled by ensuring equipment is tethered and keeping people away from the area during the work.

6.4.5 Extreme impacts

Building envelopes cannot generally be designed to resist extreme impacts, particularly vehicle impacts. Where there is a risk of low velocity impacts, such as in car parks, protective barriers may be provided.

Building envelopes should be designed and constructed such that an extreme impact, whilst it may cause structural damage, does not lead to progressive collapse of a wall.

6.4.6 Assessment of impact performance

Impact performance is assessed by conducting soft and hard body tests. The testing procedures are described in the following:

- CWCT Technical Note No, 76 - *Impact performance of building envelopes: method for impact testing cladding panels;*

- BS 5234-2: *Partitions (including matching linings). Specification for performance requirements for strength and robustness including methods of test.*

For **external surfaces** the likely impact is given by categories as described in *Table 6.4.1*.

Table 6.4.1 also shows the impact energies associated with hard and soft body tests for both the serviceability condition and the safety condition. There is no single pass or fail criterion and the results of a test are classified.

For the safety condition the results of a test are classified by risk associated with the impact as shown in *Table 6.4.2.* The adoption of a particular class of risk should be based on a risk assessment considering the following factors:

- where things will fall;
- number of people, if any, in the fall zone;
- presence of people adjacent to the damaged wall.

For the serviceability condition the results are classified by the extent of damage caused by the impact as shown in *Table 6.4.3*. The extent of damage which is acceptable will depend on:

- ease of repair;
- cost of repair;
- client acceptance of temporary damage.

Category	Description	Example	Safety		Serviceability	
			Soft	**Hard**	**Soft**	**Hard**
	Areas within 1.5m of ground					
A	Readily accessible to the public and others with little incentive to exercise care. Prone to vandalism and abnormally rough use.	External walls in vandal prone areas.	No values are given as severity of potential vandalism needs to be assessed.			
B	Readily accessible to the public and others with little incentive to exercise care. Chance of accident occurring and of misuse.	Walls adjacent to pedestrian thoroughfares when not in category A.	500 J	10 J	120 J	10 J
C	Accessible primarily to those with some incentive to exercise care. Some chance of accident occurring or of misuse.	Walls adjacent to private open gardens. Back walls of balconies.	500 J	10 J	120 J	6 J
D	Only accessible, but not near a common route, to those with a high incentive to exercise care. Small chance of accident occurring or of misuse.	Walls adjacent to small fenced decorative garden with no through paths.	No value given as risk of impact is minimal.			
	Areas more than 1.5m above ground					
E	Above zone of normal impacts from people but liable to impacts from thrown or kicked objects. May also be subject to impact during maintenance.	1.5 to 6m above pedestrian level in location categories A and B.	350 J	10J	120 J	6 J
F	Above zone of normal impacts from people and not liable to impacts from thrown or kicked objects. May also be subject to impact during maintenance.	Wall surfaces at higher positions than those defined in E above.	350 J	3 J	120 J	3 J

Table 6.4.1 - Exposure categories and impact energies for external surfaces

Class	Description
Negligible risk	• No material dislodged during test, • No damage likely to lead to materials falling subsequent to test • No sharp edges produced that would be likely to cause severe injury to a person during impact • Cladding not penetrated by impactor
Low risk	• Maximum mass of falling particle 50g, • Maximum mass of particle that may fall subsequent to impact 50g • Cladding not penetrated by impact • No sharp edges produced that would be likely to cause severe injury during impact
Moderate risk	• Maximum mass of falling particle less than 500g • Maximum mass of particle that may fall subsequent to impact less than 500g • Cladding not penetrated by impact • No sharp edges produced that would be likely to cause severe injury during impact.
High risk	• Maximum mass of falling particle greater than 500g • Cladding penetrated by impact • Sharp edges produced that would be likely to cause severe injury during impact.

Table 6.4.2 - Safety classification for external surfaces

Class	Definition	Description
1	No damage	• No damage visible from 1m • Any damage visible from closer than 1m unlikely to lead to significant deterioration
2	Surface damage of an aesthetic nature which is unlikely to require remedial action	• Dents or distortion of panels not visible from more than 5m (note visibility of damage will depend on surface finish and lighting conditions - damage will generally be more visible on reflective surfaces), and • Any damage visible from closer than 5m unlikely to lead to significant deterioration.
3	Damage that may require remedial action or replacement of components to maintain appearance or long term performance but does not require immediate action	• Dents or distortion of panels visible from more than 5m • Spalling of edges of panels of brittle materials Damage to finishes that may lead to deterioration of the substrate.
4	Damage requiring immediate action to maintain appearance or performance. Remedial action may include replacement of a panel but does not require dismantling or replacement of supporting structure	• Significant cracks in brittle materials eg cracks that may lead to parts of tile falling away subsequent to test • Fracture of panels causing significant amounts of material to fall away during test.
5	Damage requiring more Extensive replacement than 4	• Buckling of support rails.

Table 6.4.3 - Serviceability classification for external surfaces

For **internal surfaces** the likely impact is given by grades as described in *Table 6.4.4*.

There is a pass/fail criterion for the safety test and the impact should not cause penetration of the surface or structural damage. For the serviceability test there is no clear pass or fail criterion and the resulting damage is simply described in the test report.

			Safety		**Serviceability**	
Grade	**Description**	**Example**	**Soft**	**Hard**	**Soft**	**Hard**
Severe duty (SD)	Adjacent space intensively used by the public and others with little incentive to exercise care. Prone to vandalism and abnormally rough use	Major circulation and heavy industrial areas	120 J	30 J	100 J	10 J
Heavy duty (HD)	Adjacent space frequently used by the public and others with little incentive to exercise care. Chances of accident occurring and of misuse	Public circulation and industrial areas	120 J	15 J	40 J	6 J
Medium duty (MD)	Adjacent space moderately used primarily by persons with some incentive to exercise care. Some chance of accident occurring and of misuse	Office accommodation	60 J	5 J	20 J	3 J
Light duty (LD)	Adjacent space only accessible to persons with high incentive to exercise care. Small chance of accident occurring or of misuse	Domestic accommodation	60 J	-	20 J	3 J

Table 6.4.4 - Exposure grades and impact energies for internal surfaces

6.4.7 Low cycle fatigue

Fatigue is not normally a design-limiting requirement. However, wind fatigue loads may cause failure in some cases. Problems are most likely to arise where:

- flexible components interface with more rigid components;
- panels made from non-ductile materials are highly stressed.

Where there is concern that low cycle fatigue may be a problem, a test may be carried out on the components. The sequence of loads shown in *Table 6.4.5* is given in BRE Digest 346-7 – *The assessment of wind loads. Part 7: Wind speeds for serviceability and fatigue assessments* and may be used to perform a test for resistance to low cycle fatigue. Alternatively, a simple sequence of 10000 cycles of design wind pressure may be used. In each case the test should be conducted at a frequency of approximately 1 Hz.

Effective wind pressure	Number of cycles
90	1
40	960
60	60
50	240
80	5
70	14

The sequence is repeated five times followed by a single application of 100% effective wind pressure

Table 6.4.5 - Resistance to low cycle fatigue

6.4.8 Progressive collapse

Building envelopes should be designed and constructed to reduce the risk of progressive collapse. Progressive collapse occurs when failure of a single structural component, or a limited number of components, leads to far greater structural damage and potential collapse of a whole wall.

For this reason, walls are designed to have a degree of redundancy. The principal precautions are:

- principal brackets are designed such that if one construction fixing fails the remaining construction fixings are able to transfer the load;
- where framing members carry the self-weight of more than one storey height there should be an alternative load path should that framing member fail. This is not normally related to built-up walls.

6.4.9 Minimum load requirement

When designing curtain walling a minimum design wind pressure of 800 Pa is assumed. When combined with the deflection limits described in Section 6.3 this gives the wall a defined stiffness.

For a built-up wall with a brittle inner surface the allowable deflections are smaller and so the stiffness is likely to be sufficient. Similarly, for a construction with a masonry back wall.

6.5 MOVEMENT

Built-up walls are required to remain safe and serviceable when there is movement of:

- cladding materials:

  movement may occur as a result of:
  - change of temperature,
  - change of moisture content,
  - Application of loads.

- Supports:

  movement may occur as a result of:
  - floor loading,
  - wind loading,
  - seismic loading,
  - settlement,
  - creep,
  - shrinkage.

Built-up walls should be designed to accommodate movement or safely carry any induced loads resulting from restrained movement. Movement may be accommodated within the components of the wall or at joints between components.

6.5.1 Specification

The specification should give sufficient information on movement of the primary structure to facilitate design of the wall to accommodate that movement. The information required in the specification will depend on the form of construction.

For a masonry or blockwork load bearing back wall movements of the primary structure will be negligible.

For back walls comprising a frame, studs or blockwork infill the specification should detail the movement of the primary structure at the points of attachment of the building envelope. This should include:

- floor slab deflection;
- inter storey drift;
- column shortening;
- settlement.

Movement of the cladding will depend on temperature. Default values for envelope temperatures are given in CWCT *Standard for systemised building envelopes*, *Table 6.5.1*. In more extreme climates than the UK different temperatures may be specified.

External surface temperatures	
Heavy weight, light colour	-20 to +50 °C
Heavyweight, dark colour	-20 to +65 °C
Lightweight (insulated) light colour	-25 to +60 °C
Lightweight (insulated) dark colour	-25 to +80 °C
Internal temperatures	
Building empty or out of use	-5 to +35 °C
Building in normal use	+10 to +30 °C

Table 6.5.1 - Building envelope temperatures

6.5.2 Cladding movement

Temperature changes will cause materials to expand and contract. The change in dimension (ΔL) is given by:

$$\Delta L = \alpha \; L \; \Delta t$$

Where:

$L =$ original dimension,

$\Delta t =$ change of temperature,

α = the thermal coefficient of expansion and values of α for various materials are shown in *Table 6.5.2.*

Material	**Thermal coefficient of expansion (α)**	**Elastic modulus (E)**
Steel	12×10^{-6} °C^{-1}	200 kN/mm^2
Aluminium	24×10^{-6} °C^{-1}	70 kN/mm^2
PVC-U	80×10^{-6} °C^{-1}	2 – 4 kN/mm^2
Brick	5 -12 x 10^{-6} °C^{-1}	4 – 25 kN/mm^2
Concrete	8 - 14 x 10^{-6} °C^{-1}	15 – 35 kN/mm^2
Natural stone	5 -12 x 10^{-6} °C^{-1}	3 – 8 kN/mm^2
Timber (with grain)	4 -6 x 10^{-6} °C^{-1}	5 – 12 kN/mm^2

Table 6.5.2 - Material properties affecting temperature movement

Preventing the expansion or contraction by fixings or some other restraint will cause stress (σ) in the material and a corresponding force at the restraint. The stress is:

$$\sigma = \alpha \; E \; \Delta t$$

And the force (*P*) for a framing member is:

$$P = \alpha \; A \; E \; \Delta t$$

Where:

$E =$ Elastic modulus of the material,

$A =$ Cross-section of the material.

For thin sheet materials restrained expansion will cause the metal to ripple rather than it to become stressed, however restrained contraction will cause tensile stress and force in the restraints. For stiffer components such as support rails both expansion and contraction will cause stress in the component and forces at the restraints.

Moisture changes will cause materials to expand and contract. The movement may be reversible or may be permanent, for instance drying shrinkage. The moisture movements for various materials are shown in *Table 6.5.3.*

Material	Reversible movement (%)	Irreversible movement (%)
Brick (Clay or shale)	0.02 %	0.02 – 0.07 % Expansion
Brick (other)	0.02 – 0.06 %	0.02 – 0.09 % Shrinkage
Concrete	0.02-0.06 %	0.03 – 0.09 % Shrinkage
Natural stone	0.01 – 0.07 %	N/A
Timber (with grain)	N/A	N/A

Table 6.5.3 - Material properties affecting moisture movement

Applied loads will cause movement of cladding components. This has two effects:

- movements that cause components to come into contact may set up unintended load paths and transfer loads to components not designed to carry them.
- differential movement between adjacent components may:
  - rupture seals,
  - cause misalignment of drainage paths.

6.5.2.1 Accommodation of cladding movement

Movements due to uniform temperature and moisture change cause changes of dimension of the components that are small when expressed as a percentage (no greater than 0.4 % or 8mm in 2000mm for PVC-U and much less for other materials). However, the effect of the movement is more noticeable at the joints between components. 3mm of movement at a joint 15mm wide is a 20 per cent change in width of the joint. Whilst this is easily resolved for an open joint a sealant joint will require detailed assessment. Guidance on the design of sealant joints is available in CIRIA Report R178 - *Sealant joints in the external envelope of buildings: a guide to design, specification and construction*.

If the temperature or moisture change varies through the thickness of a component one surface will contract or expand more than the other. In framing members this may cause bowing and in panels it may cause dishing, *Figure 6.5.1*. Good thermal conductors such as metals will normally be at the same temperature throughout. If a component is layered, then one layer may expand or contract more than the other causing stresses at the interface between the layers and potential delamination. The ability of components to resist changes of temperature and moisture may be assessed by subjecting them to cycles of temperature and wetting. A method of test is given in MOAT No, 22 - *UEAtc Directives for the Assessment of External Insulation Systems for Walls (Expanded Polystyrene Insulation Faced with a Thin Rendering)* and ETAG 004 – *Guideline for European Technical Approval of external thermal insulation composite systems with rendering*.

Movement due to applied loads is accommodated by allowing adequate clearance between components and by designing sealed joints to accommodate movement.

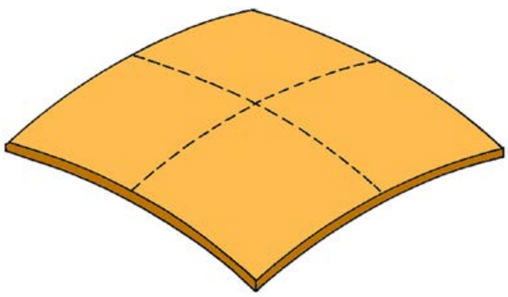


Figure 6.5.1 - Dishing of a panel

6.5.3 Movement of supporting structure

Movement of the points of attachment of a built-up wall to the primary structure will depend on:

- the supporting structure;
- the loads acting on it;
- the location of the attachment points.

For the purpose of assessing movement, the wall construction can be categorised as:

- load bearing back walls;
- blockwork infill-panels;
- stud/framed back walls.

The relevant movements of the supporting structure are those that occur after the building envelope has been installed, rendered or sealed depending on which element of the wall is being detailed. For instance, the movement affecting a back wall depends on whether it is installed before or after the formwork for a concrete slab has been removed. Similarly, movement of the floor slab caused by the weight of the back wall will occur before renders and linings are applied.

6.5.3.1 Load bearing back wall

These are stiff in plane and the points for attachment of cladding will experience negligible relative movement in any storey height. However, if the outer layers are supported at the base and only connected to the primary structure to provide out-of-plane restraint there will be differential vertical movement between the primary structural wall and the outer layers. This differential movement has to be allowed for at window openings and penetrations. This is a particular problem for built-up walls with an external leaf of masonry stacked from the ground. .

6.5.3.2 Blockwork infill panel

The infill panel is supported from below and tied in at its vertical edges and top to resist wind load. However, a gap is left along the top edge that is filled with a compressible material. This joint allows for vertical expansion and contraction of the blockwork and also for vertical movement of the floor edge due to:

- column shrinkage;
- column shortening;
- floor loading.

This joint allows the infill of one storey to move vertically relative to the one above or below. The outer layers of the wall have to accommodate this movement.

A blockwork infill panel is supported on the edge of the floor slab and will visibly crack if the edge of floor slab deflection exceeds span/1250 provided the length to height ratio of the panel does not exceed four.

Provided that the primary structure is designed to this limit then no visible cracking of the back wall will occur. Renders and lining systems are normally developed to tolerate these levels of movement but some manufacturers may set tighter limits.

6.5.3.3 Stud back wall

Studs may be stood from the floor slab such that they move vertically with it as shown in *Figure 6.5.2.* In practice the stud is normally fastened to a bottom rail which is flexible and connected to the floor slab so that it deflects with the floor. This method of construction has the disadvantage that adjacent studs have different vertical movement which will cause shear in the sheathing, lining and any render.

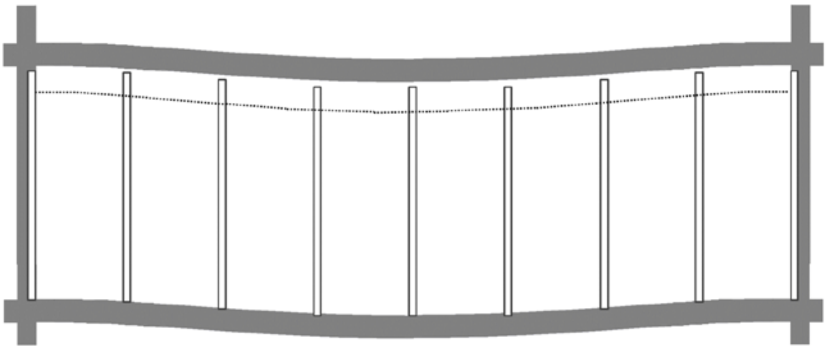


Figure 6.5.2 - Studs supported directly from the floor slab

The back wall must be able to accommodate the deflection of the floor slab. Deflection of successive floors may change due to differential loading of the floors. This will lead to a change in shape of the structural opening for the back wall.

This movement is accommodated in the connection at the head of the back wall. A c-shaped channel/deflection head is usually fixed to the soffit allowing the slab to deflect relative to the studs.

Sway or inter-storey drift may result from wind loading or seismic action. Where studs are connected to the floor slabs to form a back wall, this will induce racking movements and shear in the sheathing, lining and any render, *Figure 6.5.3*. This will cause differential movement at window to wall seals and other interfaces.

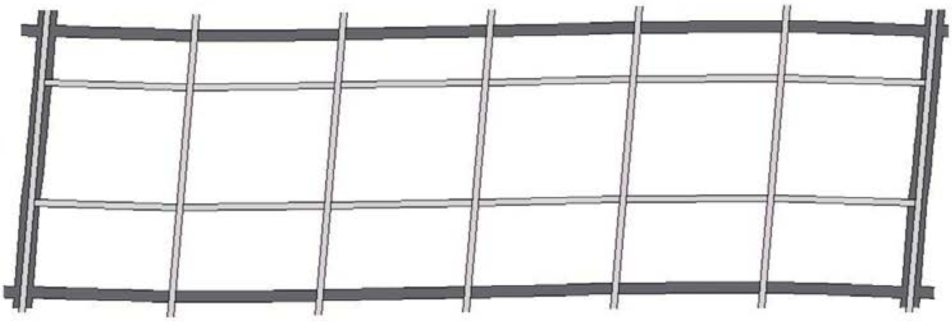


Figure 6.5.3 - Sway movement

6.5.4 Effect of movement on outer layers

Rainscreen panels with open joints are able to expand, contract and move relative to each other without restraint and no stresses are generated in them, if appropriately fixed. Renders are inherently used in large sheets and will require movement joints and appropriate reinforcement in order to have the required performance.

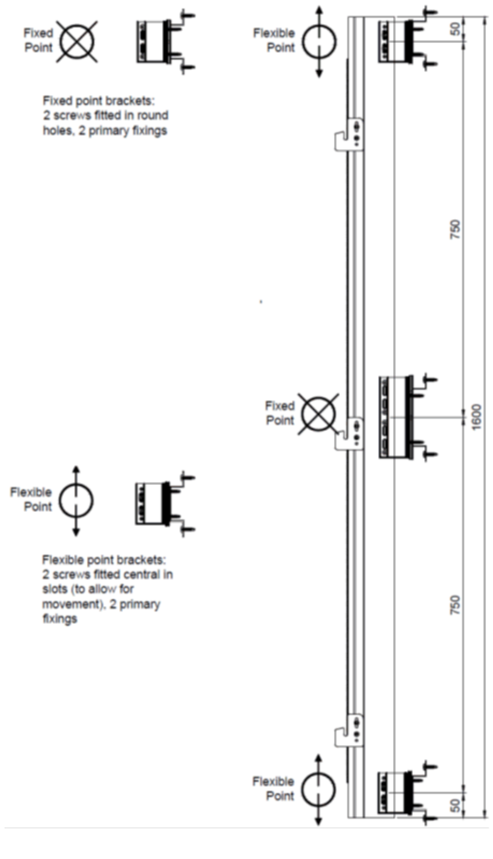
6.5.4.1 Fixing of rainscreen cladding to accommodate movement

Figure 6.5.4(a) illustrates the principles of a rainscreen fixing system to permit movement. The rainscreen rails are supported by a combination of fixed point brackets utilising circular fixing holes and flexible point brackets utilising slotted fixing holes. The fixed point bracket takes both horizontal and vertical load whereas the flexible point brackets take horizontal load and permit vertical movement. The rails shown are 1.6m long to support panels of the same length with successive rows staggered so longer rails would not be suitable in the this case. Normally rails would be storey height with additional flexible point brackets to maintain the bracket spacing.

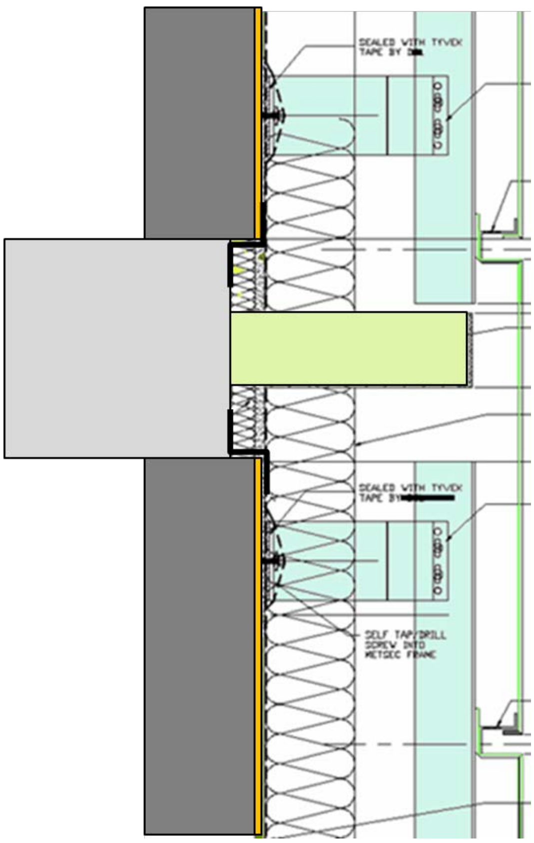
The fixed point may be at the top bottom or middle of the rail. In practice the movement at the slotted holes may be restricted if the fixings are too tight and fixing the rail at mid height reduces the movement to be accommodated at each bracket. If the height of the flexible point brackets is less than for the fixed point brackets, movement may be accommodated by flexure of the bracket rather than sliding along the slotted hole. Rails are normally in storey height lengths so only have to allow for differential movement relative to the back wall. Rails fixed in longer lengths or which extend across floor levels also have to be able to accommodate any differential movement of the floors.

In the example shown in *Figure 6.5.4(a)*, the panels are fixed to the rails by hooks. The hooks would be positioned so that the top hook would be fully engaged with the panel and support its weight. The lower hooks would only partially engage so that they can resist wind load but allow differential vertical movement between the rails and the panels. A security fixing would normally be used at the top of the panel to prevent the panel lifting off the hooks. Where a panel is supported by a single length of rail it is only necessary to consider differential movement between the rail and the panel.

Where a panel bridges a joint between two lengths of rail as shown in *Figure 6.5.4(b)*, the movements to be accommodated become greater. In this case thermal movements of the panel and rails are in the opposite direction increasing the differential movement and because the rails are fixed to different sections of back wall, any movement at the joints between the backing wall and floor also has to be accommodated by the panel fixings.



(a) Fixing arrangement for rainscreen rails



(b) Rainscreen fixing arrangement at joint in support rails

Figure 6.5.4 – Rainscreen fixing arrangements

6.5.4.2 Render systems

Renders, sheathing, insulation and lining are not free to move and stresses will be induced in them as a result of expansion, contraction and shear. For most materials it is extension of the panel or bay that is damaging as it causes tensile stresses and has the potential to crack or tear the material. Restrained contraction, or enforced extension, will cause tension, and potentially cracks, orthogonal to the direction of movement, *Figure 6.5.5(a)*.

a) Contraction b) Shear

Figure 6.5.5 – Causes of tension in a panel or bay

Enforced shear of a panel will cause tension, and potential cracks, at an angle to the edges of the panel or bay, *Figure 6.5.5(b)*. Renders, boards, taped joints and other interfaces should be selected with an adequate resistance to cracking. The manufacturer may express this as a maximum allowable direct strain or a maximum allowable movement. Alternatively, they may have prescriptive construction details that should be followed. A render may rely on an embedded mesh as reinforcement to control cracking. Where a render coat is continuous over a joint in insulation or boarding then extension is concentrated at this location and reinforcement, or additional reinforcement may be required.

Re-entrant corners at windows, doors and similar openings give rise to stress concentrations with the potential for cracks to occur in the render, see *Figure 6.5.6*. When the material contracts, a tensile zone occurs at the corner, *Figure 6.5.7(a)*. Reinforcement, or additional reinforcement, is normally required to control cracking of renders at re-entrant corners, *Figure 6.5.7(b)*.

Figure 6.5.6 – Cracking in render at a re-entrant corner

a) Tension at a corner **b) Reinforcement at a corner**

Figure 6.5.7 – Potential cracking at a re-entrant corner

6.5.5 Effect of movement on interfaces and joints

Contraction of panels or material either side of a joint will cause the joint to widen. The resulting extension in the joint will cause separation or tension in the joint filler, *Figure 6.5.8 (a)*. Similar extension will occur in any other materials bridging the joint such as a render coat or tape.

a) Direct extension b) Shear

Figure 6.5.8 – Movement at joints

Relative movement of panels parallel to a joint will also give rise to extension of the joint filler and overlying materials such as render, *Figure 6.5.8 (b)*.

6.5.6 Effect of movement on lining and fit-out

The lining will be subject to extension similar to that which occurs in renders and sheathing. Additionally, the floor slab may move relative to the lining. In these forms of construction, the air seal between the lining and the floor slab should be detailed to accommodate the relative movement.

The fit-out of a room may be either:

- stood on the floor slab;
- supported from the back wall.

In the first case it will move relative to the back wall. In the second case it will move relative to the floor slab. The ease with which these movements can be accommodated depends on the method of support and the type of fit-out.

6.6 FIRE

Walls may be required to have fire resistance to limit spread of fire to adjacent buildings or to limit the development of fire within the building. Walls may also be required to be constructed in a way that reduces the spread of fire from one part of the building to another. Building Regulations are primarily intended to reduce the risk to life of the people in and around the building. Insurance companies may require a higher level of performance to reduce the risk of property damage and building owners may require higher performance to reduce the risk to business continuity. Building owners will also be responsible for carrying out risk assessments in relation to their use of the completed building. In addition to Building Regulations, design guidance is available for some types of building. The most notable examples are for healthcare buildings for example Health Technical Memorandum 05-2: *Firecode – Guidance in support of functional provisions (Fire safety in the design of healthcare premises)* in England; similar guidance documents exist in other regions of the UK. The performance required by the Building Regulations depends on the location of the building with respect to the site boundary, the height of the building and the use of the building.

6.6.1 Building Regulations

The requirements of the Building regulations and supporting documents are complex as they address the whole building and consider different forms of construction. This section summarises the requirements as they apply to built-up walls. Some of these requirements would not apply to other forms of wall construction such as cavity masonry.

Guidance on meeting the requirement for fire performance throughout the various regions of the UK is given in the following sets of documents:

- England:
  - Approved Document B Volume 1 – Dwellinghouses – *Fire Safety,*
  - Approved Document B Volume 2 – Buildings other than dwellinghouses – *Fire Safety;*
- Northern Ireland:
  - Technical Booklet E – *Fire Safety;*
- Scotland:
  - Technical Handbook – Domestic - Section 2 – *Fire,*
  - Technical Handbook – Non-Domestic - Section 2 – *Fire;*
- Wales:
  - Approved Document B Volume 1 – Dwellinghouses – *Fire Safety,*
  - Approved Document B Volume 2 – Buildings other than dwellinghouses – *Fire Safety.*

They generally follow the same principles and the documents for England, Northern Ireland and Wales are very similar in presentation. The document for Scotland is set out very differently making comparison more difficult. Although following the same principles there are some differences in the precise requirements. There are also differences in terminology used for the reaction to fire performance of materials. In this document the European designations have been used as they apply in all jurisdictions. The references to the European classifications should be taken to include the equivalent national classifications given in *Table 6.6.1*. The terminology affected is as follows:

England ADB **Northern Ireland Technical Booklet E** **Wales ADB**		**Scottish technical Handbook**
National classification	**European classification to BS EN 13501-1**	**Risk class**
Non-combustible	A1	Non-combustible
Limited combustibility	A2	Non-combustible
Class 0	B s3, d2 or better	Low risk
Class 1	C s3, d2 or better	Medium risk
Class 2 or 3	D s3, d2 or better	High risk

Table 6.6.1 - Reaction to fire classification

The requirements in the Building Regulations that affect the construction of built-up walls relate to the following:

- fire resistance of the wall;
- junctions between external walls and compartment floors and walls;
- reaction to fire classification of exposed surfaces;
- cavity barriers;
- combustibility of materials;
- alternative provisions.

6.6.1.1 Fire resistance

External walls may be required to have fire resistance to limit spread of fire to or from adjacent buildings. The required period of fire resistance for a wall depends on the use of the building, its distance from the boundary, its height and the location of fire escape routes. Fire resistance may be required to resist fire from both outside to inside and inside to outside however in some cases it is only required to resist fire from inside to outside.

6.6.1.2 Junction between backing wall and structure

Buildings are normally divided into compartments by fire resisting floors and walls. Where an external wall meets a compartment floor or compartment wall, the junction is required to maintain the fire resistance of the compartmentation. This applies whether or not the external wall is fire resisting.

6.6.1.3 Reaction to fire of exposed surfaces

The reaction to fire properties of a material relate to the reaction of the material to a heat source. Limitations are placed on the reaction to fire properties of materials used in the external wall to restrict the spread of fire in response to either radiated heat from an adjacent building or a flame plume emerging from a window or doorway. Reaction to fire requirements is given in *Table 6.6.2.*

Location	England, Northern Ireland and Wales	Scotland
Not more than 1m from boundary	Class B s3 d2 or better	A2 or better
More than 1m from boundary, building less than 18m high and building not used for entertainment and assembly, residential care or hospitals	No requirement	No requirement
More than 1m from boundary and building height greater than 18m	Class B s3 d2 or better for surfaces above 18m C s3 d2 or better below 18m	Class B s3 d2 or better
More than 1m from boundary and less than 18m high for buildings used for assembly or recreation	C s3 d2 or better below 10m or within 10 m of a roof to which public have access	Class B s3 d2 or better
	Higher levels: no requirement	No requirement
More than 1m from boundary and less than 18m high for residential care buildings and hospitals	No specific requirement	Class B s3 d2 or better

Table 6.6.2 - Reaction to fire requirements

In the Approved Documents B (ADB) in both England and Wales the reaction to fire requirements apply to the external surface of the building. The 2000 edition of ADB also required the cavity face of a rainscreen to comply with these reactions to fire requirements. This has been dropped from the 2006 edition but has been retained by the Technical Booklet E for Northern Ireland. There is still a requirement however in ADB that where the back wall is of masonry or concrete at least 75mm thick and is not subject to the requirement for cavity barriers (see Section 6.6.1.4) then the surfaces that face into the cavity must also meet the reaction to fire requirements in *Table 6.6.2*. The requirements in the Scottish Technical Handbook apply to the materials used for the external cladding and hence may be applied to both faces of a rainscreen.

6.6.1.4 Cavity barriers

Building regulations require cavity barriers to be provided:

- To close the edges of cavities. This would include the perimeter of an area of rainscreen or an area of external insulation with a cavity and around penetrations through the cavity for windows etc.,
- On the line of compartment floors or walls,
- At maximum spacing of 20m when the materials within the cavity are non-combustible or Class B s3 d2 or better and 10m in other cases,
- A ventilation duct through a rainscreen cavity should either have the performance of a cavity barrier or be protected by a cavity barrier. If the duct passes through a fire resisting back wall the duct passing through the back wall should be fitted with a fire damper giving the same performance as the wall.

Cavity barriers are required to provide 30 minutes fire resistance. In the ADB documents and Technical Booklet E, this is specifically 30 minutes integrity and 15 minutes insulation. The Scottish Technical handbook only requires the barrier to provide integrity.

There are exceptions to these requirements in certain cases depending on the construction of the back wall. The most significant exception is where the back wall is of masonry or concrete at least 75mm thick, and the cavity does not contain combustible insulation. In addition, in Scotland the inner and out face of the rainscreen must be Class B s3 d2 or better. Under these conditions in England and Wales, cavity barriers are required to close the edge of the cavity and at compartment floor/wall locations, and in Scotland just to close the edge of the cavity.

6.6.1.5 Combustibility of materials

Reaction to fire is the response of a material or component to a heat source, in terms of spread of flame across the surface and release of heat. Materials may be classified in accordance with EN 13501-1 as A1, A2, B, C, D, E, or F with A1 being the highest performance and F being the lowest.

Approved Document B:2013 also allows performance to be tested, classified and specified in accordance with a National classification based on tests in accordance with BS 476. The relationship between National and European classification adopted in Approved document B is as follows;

European class	National class
A1	Non-combustible. Defined in Approved Document B Table A6
A2	Limited combustibility. Defined in Approved Document B Table A7
B	Class 0. Defined in Approved Document B Appendix A Clause 13
C	Class 1. Defined in BS 476 part 7

Note this Table shows the equivalence of classes in terms of the requirements of Approved Document B. Materials can only be classified using the appropriate test methods and a material classified in accordance with the national classification may give a higher or lower classification than suggested in the Table when tested in accordance with the European tests.

Table 6.6.3 – Reaction to fire classification

There are specific requirements relating to the combustibility of materials used in the construction of the wall as shown in *Table 6.6.4*. In most cases the requirements apply to tall buildings with floors more than 18 m above ground level.

England and Wales	Scotland	Northern Ireland
In a building with a storey 18m or more above ground level any insulation product, filler material (not including gaskets, sealants and similar) etc., used in the external wall construction should be of limited combustibility.	Every part of a wall within 1m of a boundary is required to be constructed of Class A2 products In non-domestic buildings, where there is a floor more than 18m above ground level, insulation in a cavity of a wall is required to be Class A2. In high rise domestic buildings external walls should be constructed from Class A2 products	Where there is a floor more than 18m above ground level any material supporting the cladding and any insulation in the wall are required to be of Class A2 or better

Table 6.6.4 - Combustibility of materials

For ADB, the limits on combustibility of materials are given above specifically refer to insulation materials and filler materials. This is now being interpreted to include all significant materials in the wall build up (see BCA Guidance note 18). Therefore where a building has a storey 18m or more above ground level **all significant materials** should be of limited combustibility (Class A2 in accordance with EN 13501-2). This includes, but is not limited to;

- Rainscreen panels,
- Insulation materials,
- Sheathing boards,
- Materials within the back wall such as plaster boards,

These requirements apply to the full height of the wall both above and below 18m.

An exception to the above may be made for small isolated components that would not significantly add to the fire load and/or contribute to fire spread. Some typical examples are discussed below. Further details are given in CWCT TN98 *Fire performance of facades – Guide to the requirements of UK Building Regulations.*

Membranes
Thin membranes for waterproofing, air tightness and vapour control may be excluded from the requirements, however they should be detailed in such a way that they do not increase the risk of fire spread by causing other materials to ignite.

Membranes sandwiched between the back wall and the cavity insulation that would not be exposed to the initial fire could be deemed as being safe. Care though should be taken when a membrane is placed on the cavity side of the insulation and membranes in this location should not pass over the front of cavity barriers. Class B rated membranes are available, and these may be specified in exposed/vulnerable areas.

Window frames
Whether framing members will contribute to the external fire spread will depend upon the materials used, and the configuration/extent of their use. A single window in a punched opening, surrounded by materials which are of limited combustibility is unlikely to present a significant risk whereas window assemblies extending past the floor slab may pose more of a risk especially if the materials used for the framing members are combustible or contain large amounts of combustible materials.

Paint finishes
Most paint finishes are combustible but due to their thickness, can generally be excluded from the requirements providing they are applied to a non-combustible substrate. The finish will need to comply with requirements for surface spread of flame.

6.6.1.6 Alternative provisions

Walls constructed in accordance with the provisions described above will comply with the Regulations however ADBs for both England and Wales, the Scottish Technical Handbook and the Technical Booklet E for Northern Ireland all permit alternative solutions provided the underlying requirements of the Regulations are satisfied. One specific alternative that is suggested in these guidance documents is to test the proposed construction in accordance with BS 8414-1 - *Fire performance of external cladding systems. Test method for non-loadbearing external cladding systems applied to the masonry face of a building* or BS 8414-2- *Fire performance of external cladding systems. Test method for non-loadbearing external cladding systems fixed to and supported by a structural steel frame* and follow the assessment criteria of BRE Guide BR 135 – *Fire performance of external thermal insulation for walls of multistorey buildings*. In the ADBs it is suggested that this may take the place of the provisions for cavity barriers, reaction to fire of the external surface and limited combustibility of the materials. In the Scottish Technical Handbook only the provisions for reaction to fire and combustibility of insulation are replaced.

The Building Control Alliance Technical Guidance Note 18 gives two further methods of demonstrating compliance;

- Desktop study,
- Holistic fire engineering.

A desktop study can be used where no actual fire test data exists for a particular cladding arrangement. It is carried out by a suitably qualified fire specialist stating whether, in their opinion, the

BRE 135 criteria would be met with the proposed system. This opinion must be backed up by test evidence (from an independent UKAS accredited testing body), either of a similar system, or data from an alternative testing standard.

Finally a holistic fire engineering approach may be taken. This takes into account factors such as building use and geometry, ignition risk, and factors restricting fire spread. This approach is more suited to larger buildings. This is covered in BS 7974, Application of fire engineering principles to the design of buildings.

6.6.2 Specification

The specification will normally require compliance with the Building Regulations. Some of the provisions of the Building Regulations depend on the overall fire strategy for the building and the specification will need to make clear what requirements apply to the wall. The most obvious requirement in this respect is any requirement for fire resistance of the wall. Compartment walls and floors also need to be identified as these affect the requirements for cavity barriers.

Specifications for rainscreen walls may make reference to compliance with the CWCT *Standard for systemised building envelopes*. Compliance with Building Regulation requirements will satisfy many of the requirements of the CWCT Standard. The effect of additional requirements in the CWCT Standard is discussed in the Construction section below.

Where the specifier requires a level of performance above that required by the Building Regulations this needs to be stated. For example, the specifier may place additional restrictions on the types of insulation that are acceptable.

6.6.3 Construction

6.6.3.1 Back wall

Where fire resistance is required it will normally be a function of the back wall. For framed back walls, fire resistance can be achieved by use of an appropriate type and thickness of sheathing or lining board which will vary according to the period of fire resistance required. Where fire resistance is required from both sides then both the sheathing and lining boards must be selected appropriately. Manufacturers should be consulted for guidance on board thicknesses and construction details to achieve the specified period of fire resistance. Masonry and concrete backing walls will also provide fire resistance.

It is common for the back wall of the built-up wall to be constructed as infill between the floors of the structure. In this case it will be necessary for the junctions between the floors or compartment walls and the backing wall to be sealed to prevent the entry of fire into any cavity in the wall. If the backing wall is fire resisting these seals should have the same duration of fire resistance as the back wall. If the back wall is not fire resisting these seals would be treated as cavity closers requiring 30 minutes fire resistance. These fire seals must be designed to allow movement between the wall and the floors particularly deflection of the floor.

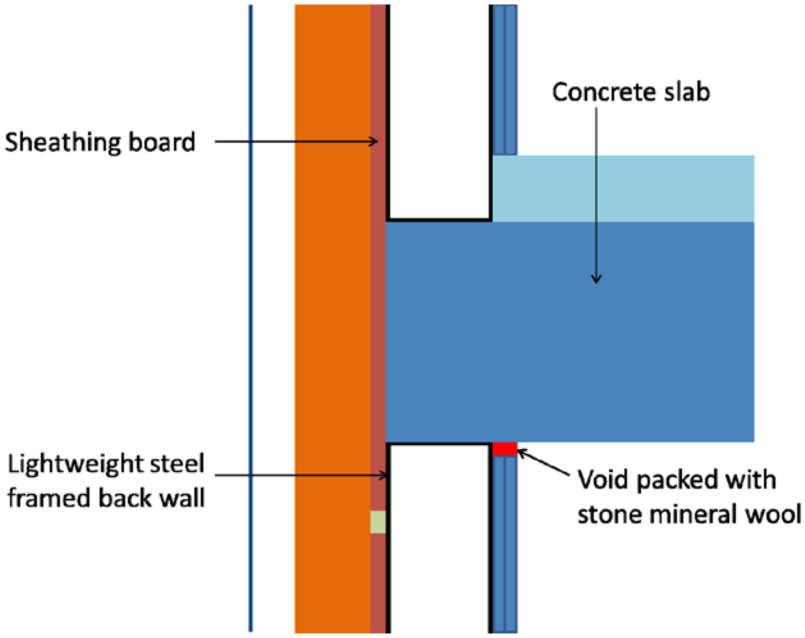


Figure 6.6.1 - Infill backing wall

Figure 6.6.1 shows compressible packing between dry lining and soffit of the slab to maintain fire resistance and permit movement. The junction between the plasterboard and the screed is not required to accommodate movement as the bottom of the wall will move with the floor. The floor slab breaks the cavity in the back wall at floor level so there is no requirement for a cavity barrier in the back wall at this location. This detail shows the board on the outer face of the stud wall running in a continuous plane just in front of the floor slab. This does not allow for possible deviation in the position of the floor slab.

These walls are constructed using proprietary products and manufacturers should be able to provide evidence to demonstrate their performance.

Walls may be constructed with a continuous back wall in front of the structure of the building. In this case it will be necessary to:

- provide fire stopping between the back wall and any compartment floors or walls. The fire stopping should provide the same period of fire resistance as the compartment wall or floor. The fire stopping must be designed to accommodate any differential movement both during normal use of the building and during a fire;
- the brackets supporting the backing wall need to ensure that it is tied to the supporting structure to prevent it moving away from the structure in a fire and allowing fire to spread past compartment floors;
- any cavity in the back wall that extends across the line of a compartment wall or floor should be provided with a cavity barrier on the line of the compartment wall or floor.

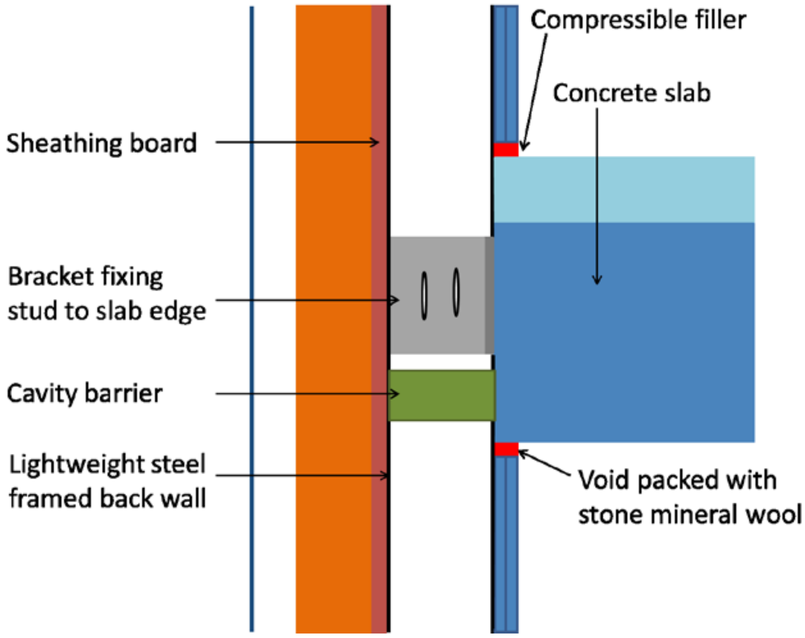


Figure 6.6.2 - Continuous backing wall

Figure 6.6.2 shows compressible packing between dry lining and soffit of the slab to maintain fire resistance and permit movement. The junction between the dry lining and screed should also be constructed in this way as the bracket is designed to permit the slab to move down relative to the dry lining. A cavity barrier should be provided in the cavity of the back wall on the line of the floor if the floor is a compartment floor.

6.6.3.2 Rainscreen

Rainscreens are normally constructed to comply with the prescriptive requirements of the Building Regulations. Testing in accordance with BS 8414-1 or -2 has not been widely adopted as the results only apply to the system as tested and these details rarely remain the same for different contracts. The three issues which affect compliance with the Building Regulations are:

- the combustibility of the insulation and other materials;
- reaction to fire performance of the rainscreen;
- provision of cavity barriers.

6.6.3.2.1 Combustibility of insulation

Mineral wool is the only commonly used insulation material that meets the requirement of Class A2 and the prescriptive requirements of the Building Regulations, for use in walls with a floor more than 18 m above ground level. Foil faced phenolic foam is commonly used in rainscreen walls but has a Class 0 reaction to fire and should therefore only be used above 18m where the system has been tested in accordance with BS 8414-1 or -2 and shown to satisfy the requirements of BRE Guide BR 135.

For walls less than 18m there is no requirement on the combustibility of the insulation or its reaction to fire classification. The most commonly used combustible insulation is a foil faced phenolic foam which gives a Class 0 reaction to fire but other foam plastic insulations are sometimes used and these may not be protected by a foil facing.

6.6.3.2.2 Reaction to fire performance of rainscreen panels

Rainscreen panels are produced from a wide variety of materials. Many including uncoated metal, stone, terracotta and fibre reinforced cement are Class A2 and these are suitable for use in all areas. Others including high pressure laminate, timber and aluminium composite material are combustible and do not meet the requirements for Class A2 but the reaction to fire classification varies depending on the grade of the material or its treatment. The requirement for the proposed facade and the performance of the material therefore need to be checked for each application. As the reaction to fire requirements required in the Building Regulations depend on the distance from the boundary a material may be suitable for parts of a building but not others.

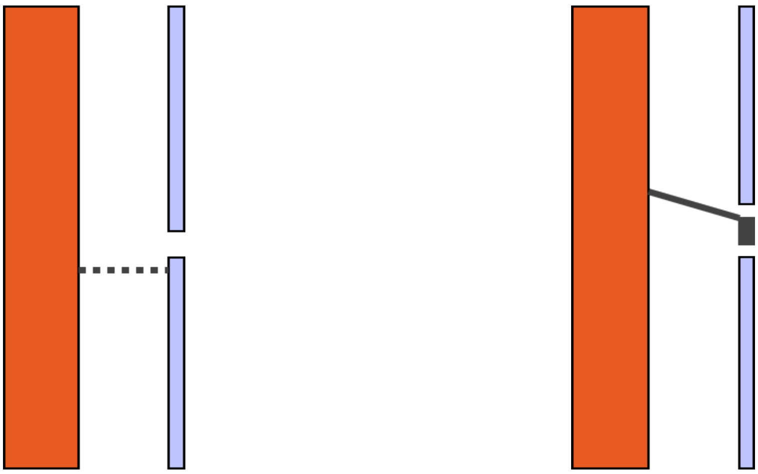
Most rainscreen panels will have the same material exposed on both the external and cavity face. There may be some panels where the properties differ due to the use of decorative finishes or treatment of the surface to improve the reaction to fire performance. In such cases it will be necessary to consider the properties of each surface and whether the cavity face is required to meet a specific performance requirement.

The CWCT *Standard for systemised building envelopes* requires both the external and internal faces of rainscreen panels to achieve Class B or equivalent reaction to fire performance. This may be a higher performance than required by the Building Regulations.

The Building Regulations do not currently set limits on the formation of falling burning debris. Following the fire at Lakanal House tower block, Camberwell in 2009 where downward fire spread was attributed to burning debris from cladding panels, this risk should be considered.

6.6.3.2.3 Cavity barriers

There is clearly a conflict between providing cavity barriers that restrict the movement of fire and smoke, and ventilation and drainage of the cavity to remove moisture. This conflict is normally overcome by the use of intumescent materials which permit drainage and ventilation under normal circumstances but expand to seal the cavity when exposed to fire as shown in *Figure 6.6.3 (a)*. The alternative is to provide a break in the cavity as shown in *Figure 6.6.3 (b)*. This satisfies the requirement of restricting the extent of the cavity but does not seal the perimeter of the resulting cavities.



(a) **(b)**

Figure 6.6.3 - Cavity barriers in rainscreen cavity (note for diagram (b), the flashing should be made of steel)

Proprietary fire barriers are available. The most common form consists of a rockwool batt sleeved with polythene with a strip of intumescent material along the outer face as shown in *Figure 6.6.4*. To be effective, these should be securely fixed to the face of the back wall or preferably, for cavity barriers on the line of compartment floors, the concrete slab edge. This will require a break in the thermal insulation in the rainscreen cavity as shown in *Figure 6.6.4*. Steel spikes are used to fix the barriers and these should penetrate the full thickness of the barrier with the tails turned over to positively hold the barrier in position. Failure to do this may allow the barrier to fall down the cavity making it ineffective as a fire barrier and possibly blocking drainage. When doing this the manufacturer's advice should be sought to ensure that this does not compromise the durability of the intumescent material.

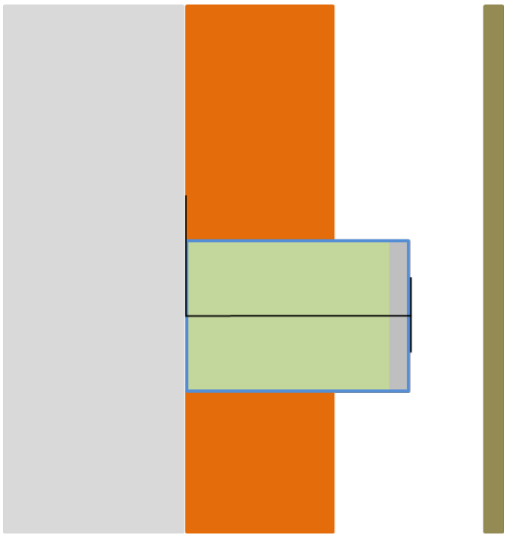


Figure 6.6.4 - Cavity barrier consisting of mineral wool and a strip of intumescent material wrapped with polythene

Intumescent cavity barriers need to be able to expand to block the cavity. A barrier must be chosen with sufficient expansion and this should be determined allowing for the nominal width of the cavity and possible increases in width of the cavity due to construction tolerances and movement of the rainscreen panels in fire. The barrier must also be selected so that sufficient opening for drainage and ventilation remains.

Proven products should be used. There is currently no harmonised European Standard or ETAG for rainscreen cavity barriers so CE marking is not possible. Manufacturers carry out tests in accordance with general fire testing principles but these may not accurately reflect performance in a rainscreen cavity with a flexible rainscreen panel. Tests carried out by different manufacturers may also differ. BRE [(1)] recommends that a large scale test in accordance with BS 8414-1 or -2 is the most reliable form of test but the performance in this test depends on details of the rainscreen used in the test and it is not practical to carry out this test on a project basis. The Association for Specialist Fire Protection (ASFP) has published a small scale test for cavity barriers, TGD 19 Fire resistance test for open-state cavity barriers. This is being developed to form a European standard, EN 1364-6, which has been published in draft form.

BRE research [(1)] suggests that a break in the rainscreen support rails is required so that the cavity barrier is not interrupted by rails. This is possible for barriers on the line of floors as rails are normally fixed in independent storey height sections. It is not so practical around window openings.

The requirement for fire barriers to prevent fire spread in a large cavity is understandable and can be achieved with intumescent barriers as described above. For rainscreen walls, the requirement to seal the edge of the cavity is less easy to achieve and the benefit is less clear. Most rainscreens have a large number of joints and even if the edge of the cavity is sealed, fire may be able to enter or leave the cavity through these joints. A practical approach might be to detail the bottom of the cavity to minimise the risk of entry of rising flames and to ensure that flames escaping from the top of a cavity are unlikely to lead to spread of fire to other parts of the building.

Any relaxation in the application of the Building Regulations needs to be agreed with the Building Control Authority.

6.6.3.2.4 Additional requirements of CWCT *Standard for systemised building envelopes*

The CWCT Standard introduces additional requirements for the fixing of insulation, routeing of services within rainscreen cavities and use of rainscreen cavities as part of the ventilation system of the building.

The CWCT Standard requires one non-combustible fixing per square metre or batten of insulation to prevent detachment in the event of fire. An explanatory note suggests that this requirement can be waived if the insulation is not part of the fire resisting element of the whole wall and the collapse of insulation in a cavity during a fire is only considered to be fortuitous in restricting fire spread within the cavity. This does not affect the need to provide cavity barriers as described above.

The CWCT Standard states that electrical and mechanical services shall pass directly through the wall and shall be sealed to the air barrier.

The CWCT Standard states that the rainscreen cavity should not be used to supply air to or as an exhaust for the building ventilation system. Building envelope systems have been developed that use a cavity as a passive solar collector to warm ventilation air.

6.6.3.3 External wall insulation systems (EWIS)

EWIS are normally supplied and installed as a complete proprietary system which is more amenable to the application of the BS 8414-1 or -2 tests and several systems have been tested in this way and assessed in accordance with BRE Guide BR 135. The manufacturer will normally supply a product that has previously been tested and it will be necessary to ensure that the system is installed in the same way as during the test. For tested systems, the Building Regulation requirements will be satisfied in England, Northern Ireland and Wales by the use of the system in the same way as in the test. In Scotland it will also be necessary to provide cavity barriers if the system contains a drained cavity although it would normally be necessary to include these in order to pass the test. This procedure can permit the use of combustible insulation such as polystyrene on tall buildings and both manufacturers and specifiers may want to limit the use of combustible material particularly thermoplastic materials that may melt and form burning droplets. EWIS are often backed by Agrément certificates which may stipulate that limited combustibility insulation should be used for buildings with a floor more than 18m above ground level.

EWIS can also be constructed to comply with the prescriptive requirements of the Building Regulations. The three issues which affect compliance with the regulations are:

- the combustibility of the insulation;
- reaction to fire performance of the external render;
- provision of cavity barriers.

6.6.3.3.1 Combustibility of insulation

Mineral wool is the only commonly used insulation material that meets the requirements of Class A2 and hence is acceptable, under the prescriptive requirements of the Building Regulations, for use in walls with a floor more than 18 m above ground level.

For walls less than 18m above ground level there is no requirement on the combustibility of the insulation or its reaction to fire classification except for walls within one metre of the boundary in Scotland where insulation of Class A2 is required. There is no explicit requirement in the Building Regulations for fire breaks in combustible insulation unless there is a cavity. Where a cavity is present, as recommended in this document, cavity barriers must be provided as discussed below and fire breaks will be required in the insulation for cavity barriers to be effective.

BRE research [(1)] has shown that unless fire breaks are provided in combustible insulation, vertical fire spread can occur. This is likely to be more rapid and extensive for thermoplastic materials like polystyrene which melt in the early stages of a fire increasing the disruption to the render and exposing the insulation directly to the fire. Fire can then spread in voids formed by the melting insulation. Burning debris from the insulation can also cause downward fire spread. Thermoset insulation materials, such as phenolic foam, do not melt but will char behind the render in the area affected by the fire. If the render is disrupted and delaminates from the insulation exposing the insulation directly to the fire, flame spread will occur over the face of the insulation. This may cause further delamination of the render and fire spread.

BRE [(1)] recommends incorporating fire breaks in the insulation at floor levels to control fire spread. Fire breaks should be:

- at least 100mm high and form a continuous band through the insulation;
- formed of non-combustible insulation and bonded and tied to the back wall and the render finish to prevent the formation of a fire path between the back wall and the fire break or between the fire break and the render.

These recommendations have been endorsed by The Insulated Cladding and Render Association (INCA) [(2)]

6.6.3.3.2 Reaction to fire performance of render finish

Traditional cement or lime based render is non-combustible and is suitable for use in all areas. EWIS may use polymer based materials for the render or for decorative surface treatments. These materials are combustible and the suitability of the reaction to fire performance should be checked with the manufacturer.

In Scotland walls within one metre of the boundary and walls of high rise domestic buildings are required to be constructed of materials of Class A2. This would prohibit the use of combustible render materials unless they satisfy the requirements of BRE Guide BR 135.

6.6.3.3.3 Cavity barriers

In this document it is recommended that a cavity is provided in walls with external insulation as an additional defence against rain penetration. Cavities provided for this purpose would require cavity barriers in the locations specified by the Building Regulations. Cavities provided in EWIS are generally 15 to 20mm wide and can be sealed by strips of intumescent material which will allow drainage to be maintained under normal circumstances. Although the specified cavity width may be 15 to 20 mm, the as constructed width may vary from this and this must be taken into account when selecting appropriate barriers. Cavity barriers will not form a fire seal in conjunction with combustible insulation hence where a combustible insulation is used it must be replaced by a limited combustibility material at cavity barrier positions. Some edges at the cavity, particularly vertical edges may be permanently sealed by the render and not need to be closed by cavity barriers.

6.6.3.3.4 Additional considerations

The fire performance of EWIS depends on the render being held in place and protecting the insulation, particularly when combustible insulation is used. Fixing systems may use adhesives and/or mechanical fixings which may be metal or plastic. For many years BRE [(3)] has recommended one stainless steel fixing per square metre of insulation with the fixing designed for the increased duty that may be required under fire conditions. The use of such fixings to hold the render base coat rather than just the insulation may be more effective.

References

1 *S Colwell and T Baker, Fire performance of external thermal insulation for walls of multi-storey buildings, Third Edition, BR 135, 2013, 24pp, ISBN 978-1-84806-234-4*

2 *INCA Technical Guide 01 Fire protection requirements for EWI systems*.

3 *BRE External walls: external combustible plastic insulation: fixings BRE Defect Action Sheet 132, Bracknell, HIS BRE Press, 1989*.

6.7 THERMAL PERFORMANCE

The thermal performance of any façade is becoming increasingly important. Recent concerns regarding climate change and energy use in buildings have resulted in the tightening of many national regulations on thermal performance, meaning that an ever greater thickness of insulation is now required in new buildings.

Built-up walls, either rainscreens or insulated render systems, are well suited to this as the insulation thickness can be easily varied to suit the project, without significantly changing the overall wall construction. Insulation thicknesses in excess of 100mm are often required to give the necessary thermal performance. Whilst such thicknesses do not present technical problems, there may be conflicts between this and other elements of the wall design, particularly the overall depth of the cladding zone. This is more of an issue for a rainscreen system where the rainscreen cavity will further add to the overall thickness of the wall.

In addition to simple U-values, thermal bridging and interfaces are also crucial factors in the overall thermal performance of the wall. A coordinated approach to the design and construction of the complete façade is required to ensure that interface details do not impact the performance of the wall (see Chapter 2).

This section looks at the thermal performance of a built-up wall in terms of the U-value. The U-value is a measure of heat loss through the façade and is a key parameter in terms of the energy required for heating a building. The heat loss through a wall will also influence the risk of condensation occurring, which is discussed in greater detail in Section 6.8.

The lowest U-values will not necessarily result in the lowest overall energy use for a building, particularly commercial/office buildings where internal loads (i.e. heat from occupants, IT equipment and lighting) can be significant. Assessment of overheating requires sophisticated whole-building analysis which is beyond the scope of this document.

6.7.1 Building regulations

U-value requirements in the Building Regulations throughout the various regions of the UK are given in the following sets of documents:

- England:
    - Approved Document L1A – *Conservation of fuel and power in new dwellings* (AD L1A – E)'
    - Approved Document L1B – *Conservation of fuel and power in existing dwellings* (AD L1A – E),
    - Approved Document L2A – *Conservation of fuel and power in new buildings other than dwellings* (AD L1A – E),
    - Approved Document L2B – *Conservation of fuel and power in existing buildings other than dwellings* (AD L1A – E);
- Northern Ireland:
    - Technical Booklet F1 – *Conservation of fuel and power in dwellings* (TB F1),
    - Technical Booklet F2 – *Conservation of fuel and power in buildings other than dwellings* (TB F2);
- Scotland:
    - Technical Handbook – Domestic – Section 6 – *Energy* (TH D6),
    - Technical Handbook – Non-Domestic – Section 6 – *Energy* (TH ND6);
- Wales:
    - Approved Document L1A – *Conservation of fuel and power. New dwellings* (AD L1A – W),
    - Approved Document L1B – *Conservation of fuel and power. Existing dwellings* (AD L1A – W),
    - Approved Document L2A – *Conservation of fuel and power. New buildings other than dwellings* (AD L1A – W),

- o Approved Document L2B – *Conservation of fuel and power. Existing buildings other than dwellings* (AD L1A – W).

The U-value requirements for opaque walls in the various regulatory guidance documents are given in *Table 6.7.1* below. The stated value represents the area-weighted average value for all opaque wall elements.

Region	Document	Building Type	Condition	U-value (W/m^2K)
England	AD L1A - E	New dwelling		0.30
	AD L1B - E	Existing dwelling	New wall	0.28
			Retained wall - upgraded	0.30[1]
	AD L2A - E	New non-dwelling		0.35
	AD L2B - E	Existing non-dwelling	New wall	0.28
			Retained wall - upgraded	0.30[1]
Northern Ireland	TB F1	New dwelling		0.30
		Existing dwelling	New wall	0.28
			Retained wall - upgraded	0.30[1]
	TB F2	New non-dwelling		0.35
		Existing non-dwelling	New wall	0.28
			Retained wall - upgraded	0.30[1]
Scotland	TH D6	New dwelling		0.22
		Existing dwelling	Retained wall - upgraded	0.30
			New wall	0.17/0.22[2]
	TH ND6	New non-dwelling		0.27
			Shell only	0.23
		Existing non-dwelling	Retained wall - upgraded	0.30
			New wall	0.25
Wales	AD L1A - W	New dwelling		0.21
	AD L1B - W	Existing dwelling	New wall	0.21
			Retained wall -upgraded	0.30[1]
	AD L2A - W	New non-dwelling		0.30
	AD L2B - W	Existing non-dwelling	New wall	0.21/0.26[3]
			Retained wall - upgraded	0.30[1]

[1] This refers to walls of the existing building that due to works being carried out come under Building Regulations approval. Where this is the case, existing walls with U-values greater than 0.70 W/m^2K should be upgraded (to 0.30 W/m^2K) provided it is technically, functionally and economically feasible.
[2] Where existing walls of a dwelling have a U-value greater than 0.70 Wm^2K the new wall of an extension is to have a maximum U-value of 0.17 W/m^2K. If the U-value of the existing walls lowers than 0.70 W/m^2K then the new wall of an extension is to be a maximum U-value of 0.22 W/m^2K.
[3] For buildings which are essentially domestic in character (e.g. student accommodation, care homes etc.) maximum U-value of new wall is to be 0.21 W/m^2K. Maximum U-value of 0.26 W/m^2K applies to all other buildings.

Table 6.7.1 - Wall U-values requirements in UK regulatory guidance documents

It should be noted that the U-values given in *Table 6.7.1* are maximum (worst) allowable average U-values rather than target values, and the required wall U-values may need to be considerably lower in order to meet the CO_2 target emissions rate for the building. Building Regulations are revised regularly and it is advisable to make reference to the regulatory guidance documents for any changes to thermal performance requirements.

U-values in the region of 0.20 W/m^2K and lower may be specified for the built-up wall. Such values require significant levels of insulation, both behind the external finish and possibly between the studs of the backing wall. In addition, careful design, detailing and workmanship to ensure the effects of thermal bridges within the wall and at interfaces and penetrations are minimised will be essential. Limiting the effect of thermal bridging is a requirement of the Building Regulations and performance criteria are included in the aforementioned regulatory guidance documents.

For a given thickness of insulation, a lower U-value is often possible with an external insulated render system because typically there are fewer thermal bridges than with a rainscreen system:

- no brackets penetrating the insulation layer;
- rails, if present, are often plastic and are fully embedded within the insulation so are not exposed to the external environment, which minimises their impact;
- adhesive bonding of the insulation to the backing wall removes/minimises mechanical connections.

For both rainscreens and render systems insulation thicknesses in excess of 200mm may be required where very low wall U-values are specified. Such thicknesses may present certain technical issues and early consultation with manufacturers is advisable in order to ensure a feasible solution is obtained. In addition to this, the cost of the wall increases significantly when considerable thicknesses of insulation are required, not only due to the cost of the extra insulation but also the larger brackets and fixings that will be required.

It should be noted that simply reducing the U-value of the built-up wall is not necessarily the most cost effective way of reducing the CO_2 emissions from the building, particularly when low values are already being proposed. Other factors such as improving the air tightness or changing the glass specification may be a more straightforward and economical way of achieving a better overall performance.

6.7.2 Specification

The thermal performance specification of a façade will vary from project to project. Depending on the configuration of the wall and how the different façade packages are split up, a typical specification may include:

- the overall U-value of the façade (for example where a single specialist contractor is responsible for the whole façade and can select a combination of wall and window U-values which meet the overall target); and/or
- the average U-value of the opaque areas of the façade; and/or
- the average U-value of the opaque areas and the windows.

When calculating the overall U-value of the built-up wall it is important to establish who is responsible for assessing the interface between the built-up wall and any windows which may be present and the interface to any adjacent areas of cladding such as a curtain wall. Likewise, other features which affect the thermal performance, such as service penetrations, brackets for shading devices, balconies, signage etc. should also be assessed.

The specification for the built-up wall may also stipulate the insulation material which is to be used. This may be done for reasons such as fire or acoustic performance. In addition, the insulation used will largely determine the thickness of the wall which is important in terms of the impact it has on useable floor area and also in the design and construction of interfaces with other elements of the wall.

Alternatively, the thickness of the cladding zone may be specified which may also limit the insulation options available, i.e. there may be only one insulation material which will give the required U-value with the thickness allowed.

Requirements for U-values of built-up walls in the region of 0.20 W/m^2K are not uncommon, and in some cases even lower values may be needed.

6.7.3 Assessment

The overall U-value of the built-up wall can only be assessed as a complete wall.

Most built-up walls are split into different packages (rails, sheathing, insulation etc.) and therefore there is no single contractor responsible for delivering the complete wall.

There are many factors which will influence the thermal performance of a built-up wall, including:

- insulation thickness and type;
- backing wall construction:
  - solid,
  - stud:
    - metal or timber studs,
    - stud spacing,
    - insulation between studs;
- method of attachment of insulation:
  - adhesive,
  - mechanical;
- bracket configuration:
  - material,
  - size,
  - spacing,
  - thermal isolation;
- rail configuration:
  - penetration into the insulation layer;
- interfaces with other elements:
  - windows and doors,
  - adjacent areas of cladding;
- thermal bridging.

Because there are so many elements which affect the performance, the overall U-value can only be assessed once all the details of the wall have been finalised.

Insulation boards tend to have a lower thermal conductivity than mineral wool insulation materials and may therefore be specified/used when a lower U-value is required. In order to realise the full performance of any insulation material it is key that it is installed correctly and that there are no gaps which would act as thermal bridges and limit the performance (see Section 6.7.5).

'Soft' insulation materials such as mineral wool expand to fill small gaps around brackets etc., whereas rigid insulation boards do not. Therefore, extra care should be taken to ensure that they are installed in such a way that gaps are minimised and the performance is not impaired.

6.7.3.1 Material properties

The key parameter required for thermal analyses is the thermal conductivity, λ, of a material. The thermal conductivity is a function of:

- orientation, for example along or across the grain in timber;
- temperature;
- density;
- moisture content.

Most materials are isotropic (properties are the same in all directions) and do not absorb water, but there are a few notable exceptions such as timber and some insulation materials.

Material properties may change over time – the thermal conductivity changes as the structure changes. This may apply to foamed plastic insulation materials blown other than by air. In such cases the declared value should represent the average over 25 years.

Generic material properties are given in Standards and guides, including:

- BS EN ISO 10077-2 - *Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. Numerical method for frames;*
- BS EN 12524 - *Building materials and products. Hygrothermal properties. Tabulated design values*;
- CIBSE Guide A – *Environmental design*.

Where products are covered by a harmonised European standard (EN) or a European Technical Approval (ETA), product declarations should conform to the requirements of the EN or ETA.

In other cases, the declaration of thermal properties should correspond to minimum thermal performance – in other words the thermal resistance should be at least that declared, or the thermal conductivity or thermal transmittance should be not more than that declared.

Where values from manufacturers are used it is important to ensure that they have been measured with reference to the correct Standard.

The heat transfer across a cavity is a combination of radiation and conduction/convection, and is usually given in the form of a thermal resistance. The value depends on the:

- size of the cavity;
- heat flow direction;
- ventilation of the cavity.

See Section 6.7.8 for further details.

6.7.3.2 Software

There are several façade specific software packages used for thermal analysis, including:

- BISCO (2D);
- TRISCO (3D);
- Flixo (2D);
- Therm (2D);
- HEAT2 (2D);
- HEAT3 (3D).

The software listed has all been validated against the benchmark examples given in BS EN ISO 10077-2 and BS EN ISO 10211 - *Thermal bridges in building construction. Heat flows and surface temperatures. Detailed calculations*, described in Section 6.7.4.

Alternatively, general finite element software can be used, however the boundary conditions (temperatures and surfaces resistances) and cavity rules (describing heat flow across cavities due to convection and radiation) would need to be applied manually.

The software above can be used to calculate the U-value of many built-up walls in addition to modelling interfaces and junctions between cladding elements and assessing the risk of condensation. 3D analysis may be required where point thermal bridges are present (see Sections 6.7.5 and 6.7.6).

Many manufacturers also provide U-value calculation software which may be able to be used for simple built-up walls. When simple U-value calculators such as these are used it is important to appreciate their limitations, such as when a metal stud back wall is used.

6.7.4 Standards and guidance

Various Standards can be used to calculate the overall U-value of a built-up wall, and the additional heat transfer which occurs at interfaces/junctions. The Standards used will depend on the configuration of the built-up wall.

6.7.4.1 BS EN ISO 6946: 2007 - Building components and building elements – Thermal resistance and thermal transmittance – Calculation method

The Standard gives a calculation methodology for simple homogeneous layered elements, for example a masonry back wall with external insulation.

It also gives an approximate method for calculating stud backing walls, however due to the nature of the heat transfer this method is only applicable to timber stud walls. The effects of metal studs and other elements such as brackets and support rails have to be assessed via computer simulation.

In addition, the Standard gives guidance on:

- surface resistances;
- the thermal resistance of air layers;
- rules for ventilation of air cavities.

6.7.4.2 BS EN ISO 10211:2007 - Thermal bridges in building construction. Heat flows and surface temperatures. Detailed calculations

This Standard is used where BS EN ISO 6946 is not appropriate. This includes calculating the effect of details such as:

- brackets;
- rails;
- fixings.

The Standard is also used to calculate the effect of thermal bridging at junctions and interfaces.

6.7.4.3 Other guidance documents

Other documents are available giving guidance in the calculation of U-values of built-up walls. These include:

CWCT - *The thermal assessment of window assemblies, curtain walling and non-traditional building envelopes*, 2010:

- ways of improving the thermal performance;
- rainscreen U-values:
  - linear thermal bridges within wall elements,
  - point thermal bridges within wall elements.

BRE BR 443 - *Conventions for U-value calculations*, 2006:

- numerical methods and simplified models;
- thermal properties of materials and products;
- issues concerned with U-value calculations;
- U-values for walls, roofs, floors, windows, doors.

BRE Digest 465 – *U-values of light steel-frame construction*

- simplified calculation method for steel frame back walls that are outside of the scope of BS EN ISO 6946,
- Applies to cold frames (where all the thermal insulation is between the steel studs) and hybrid frames (where some insulation is between the studs and some is outside of the studs).

BRE BR 497 - *Conventions for calculating linear thermal transmittance and temperature factors, 2007*:

- rules for numerical modelling;
- thermal bridging at junctions;
- temperature factors;
- point thermal bridges

BRE IP 1/06 - *Assessing the effects of thermal bridging at junctions and around openings*, 2006:

- numerical modelling:
  - calculating the temperature factor,
  - calculating thermal transmittance,
  - numerical modelling of details around openings;
- limiting the risk of surface condensation or mould growth:
  - avoiding mould growth in buildings,
  - limiting the risk of surface condensation in buildings;
- default values of thermal transmittance for generic junction types.

6.7.5 Thermal bridging

A thermal bridge is defined as a part of the building envelope where the otherwise uniform thermal resistance is significantly changed by:

- full or partial penetration of the building envelope by materials with a different thermal conductivity; and/or
- a change in thickness of the fabric; and/or
- a difference between internal and external areas, such as occur at wall/floor/ceiling junctions.

Thermal bridges have three primary consequences:

- a change in heat flow rate and therefore an increase in the U-value of the façade;
- a change in internal surface temperature and an increased risk of surface condensation;
- a possible change in temperature within the wall construction and an increased risk of interstitial condensation.

Thermal bridges may exist for a number of reasons:

- poor design;
- the nature of the construction;
- workmanship.

Figure 6.7.1 shows two examples of thermal bridging. The image on the left shows a thermal bridge caused by poor workmanship – there are gaps in the insulation which will result in greater heat flow at those points. The image on the right shows an infrared image of the internal surface of a steel framed backing wall. The effect of the studs on the internal surface temperature is clearly visible.

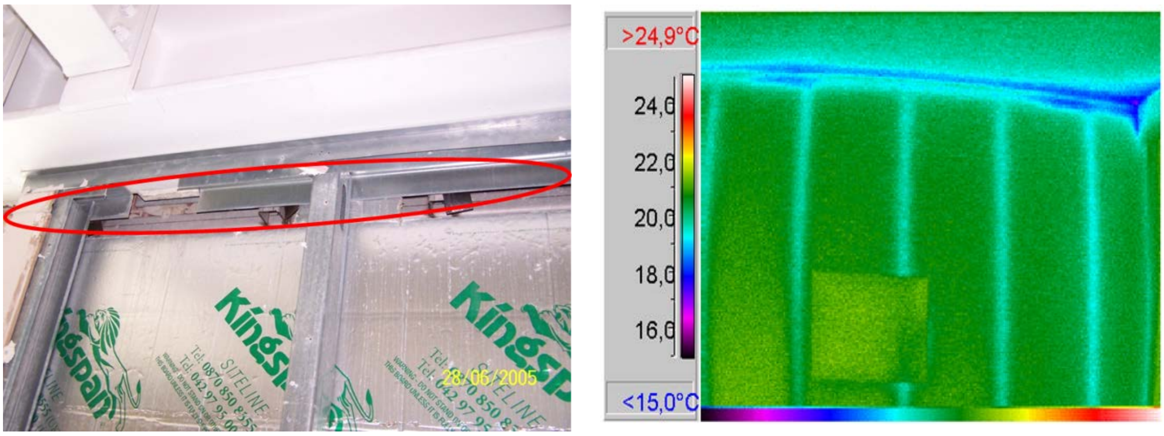


Figure 6.7.1 - Thermal bridging due to poor workmanship (left) and construction type/design (right)

Thermal bridging cannot be completely eliminated, however measures should be taken to minimise the effects, including the use of:

- thermal breaks and other separation;
- non-metal components in areas of high heat transfer, such as behind rainscreen brackets;
- appropriately placed insulation.

Thermal bridging should be quantified by calculation according to BS EN ISO 10211.

6.7.6 U-values

In general, the heat transfer through a built-up wall is made up of a:

- 1-dimensional component – the centre panel U-values of the wall;
- 2-dimensional component – linear thermal bridges (ψ-value) due to continuous elements such as cladding support rails;
- 3-dimensional component – point thermal bridges (χ-value) due to discrete components such as brackets and fixings.

These elements are illustrated in the rainscreen shown in *Figure 6.7.2* below.

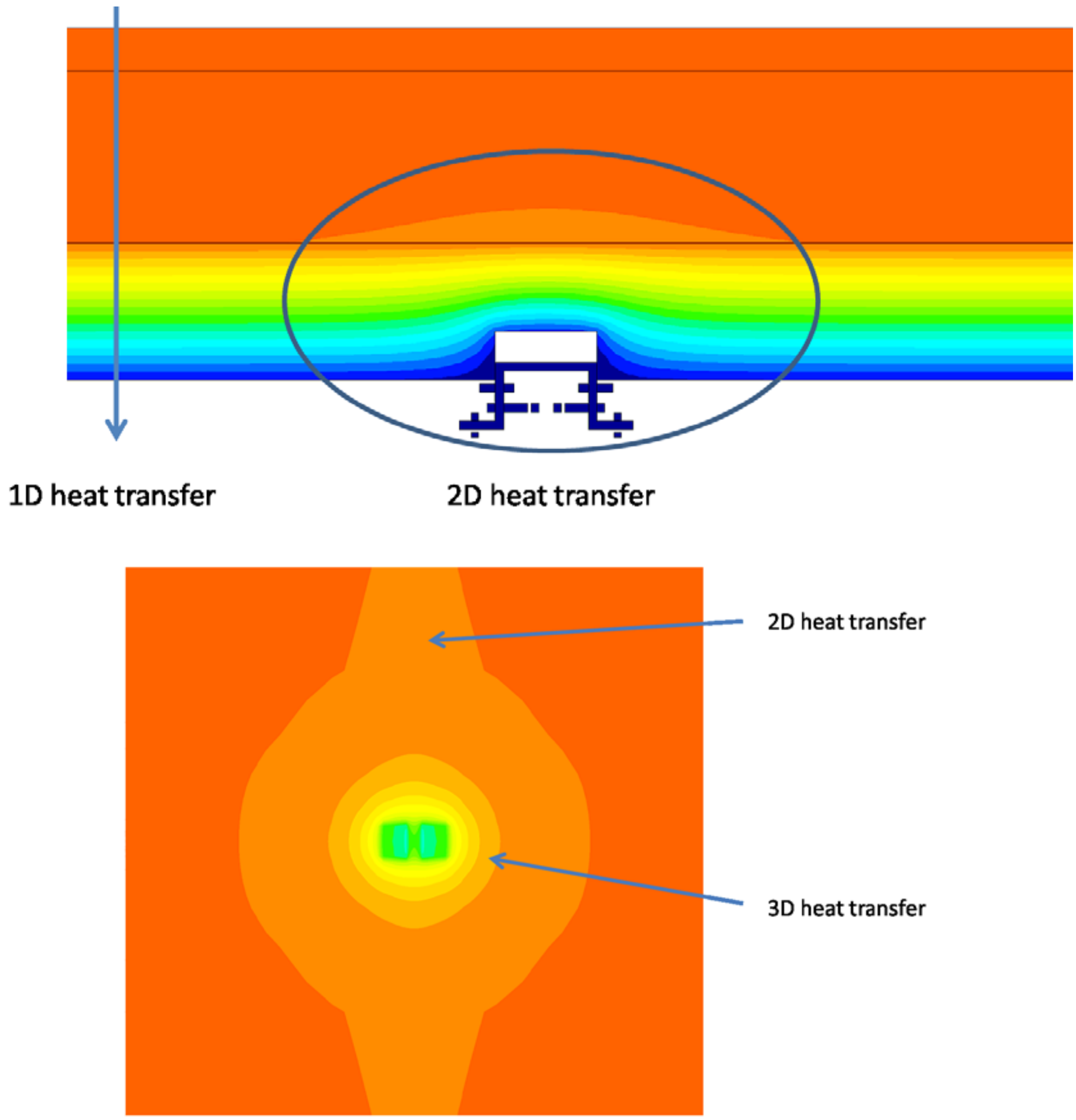


Figure 6.7.2 - Components of heat transfer

1D heat transfer occurs through homogeneous sections of the wall that are far enough away from the influence of thermal bridges etc.

2D heat transfer occurs where continuous elements disrupt the otherwise uniform insulation within the wall. In addition to support rails and the like, simply reducing the insulation thickness at any point in the wall (such as behind a vertical cladding rail) forms a linear thermal bridge, resulting in greater heat flow and a change in the temperature distribution through the wall.

Figure 6.7.3 shows how the position of the rainscreen cladding rail, and the level of insulation behind it can affect the resulting thermal bridge. The values given should be taken as a guide only; real values will depend on the wall build-up, type and thickness of insulation and rail material, amongst other factors.

(a) shows the case where there is no insulation behind the cladding rail resulting in significantly more heat loss and lower temperatures through the wall.

(b) shows the case where there is a reduced thickness of insulation behind the cladding rail. This results in less heat loss and warmer temperatures through the wall. The heat loss is 23 per cent that of (a).

(c) shows the case where the insulation is uninterrupted behind the cladding rail. Here, due to the way such cases are calculated, the rail causes no thermal bridging effect.

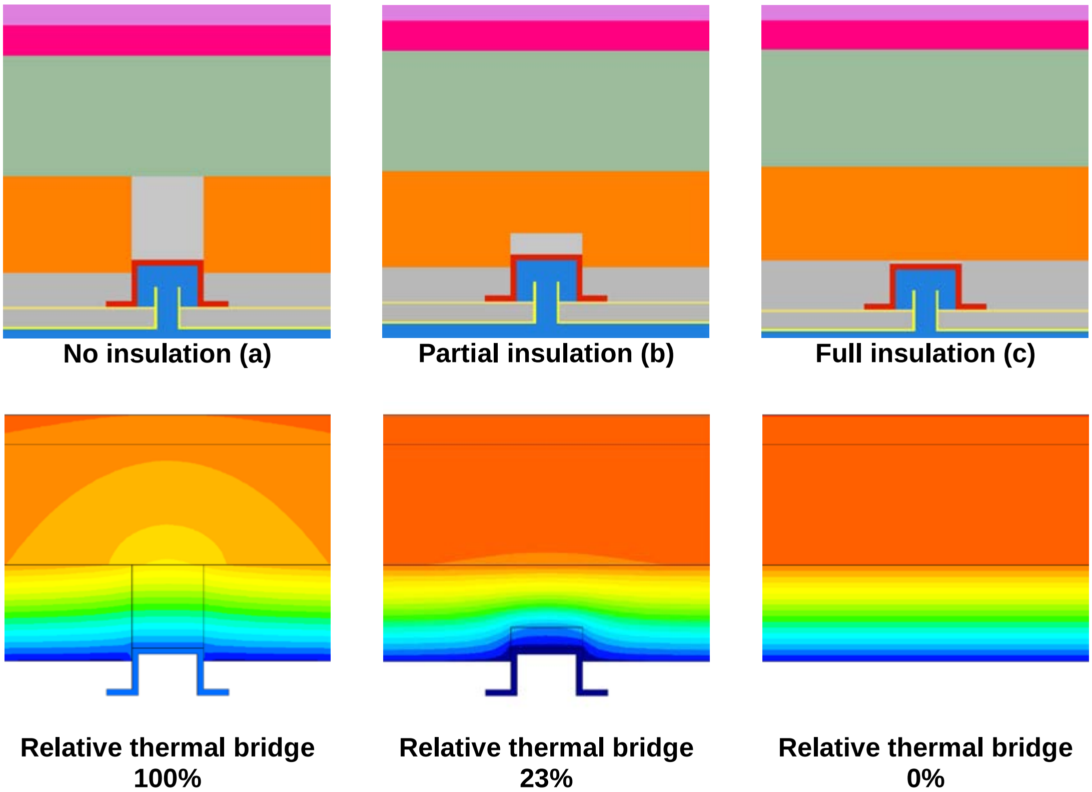


Figure 6.7.3 – Effect of rail/insulation position on linear thermal bridging

3D heat transfer occurs where very localised elements form thermal bridges. Due to the small area in question the additional heat loss caused by point thermal bridges can often be accounted for by improving other areas of the wall, such as using slightly thicker insulation. Perhaps of greater concern is the effect they have on the temperature distribution through the wall, and the increased risk of condensation forming that this brings.

There are two approaches which can be taken in the calculation of the overall U-value of a built-up wall:

- Single assessment method;
- Component assessment method.

The methodology used will depend on exactly what is required from the calculation.

6.7.6.1 Single assessment method

This method uses a single 3D model with cut-off planes (which limit the size of the simulation model) based on the vertical and horizontal centres of the brackets and rails/studs.

Figure 6.7.4 shows a built-up wall consisting of a:

- steel framed backing wall (150mm deep studs at 600mm horizontal centres);

- insulation within the rainscreen cavity;
- bracket for cladding rail (100mm deep, at 700mm vertical centres).

The vertical cladding rail is excluded from the simulation model as it sits outside of the insulation within the rainscreen cavity and therefore does not form a linear thermal bridge.

The overall U-value can be calculated using the following equation;

$$U = \frac{Q}{A.\Delta T}$$

Where:

- Q is the heat flow from the 3D simulation, in W;
- A is the area of the model, in m^2;
- ΔT is the temperature difference between the warm and cold environments, in K.

For the example in *Figure 6.7.47.4*:

- Q = 2.43W;
- A = 0.60 x 0.70 = $0.42m^2$;
- ΔT = 20K;
- U = 0.29 W/m^2K.

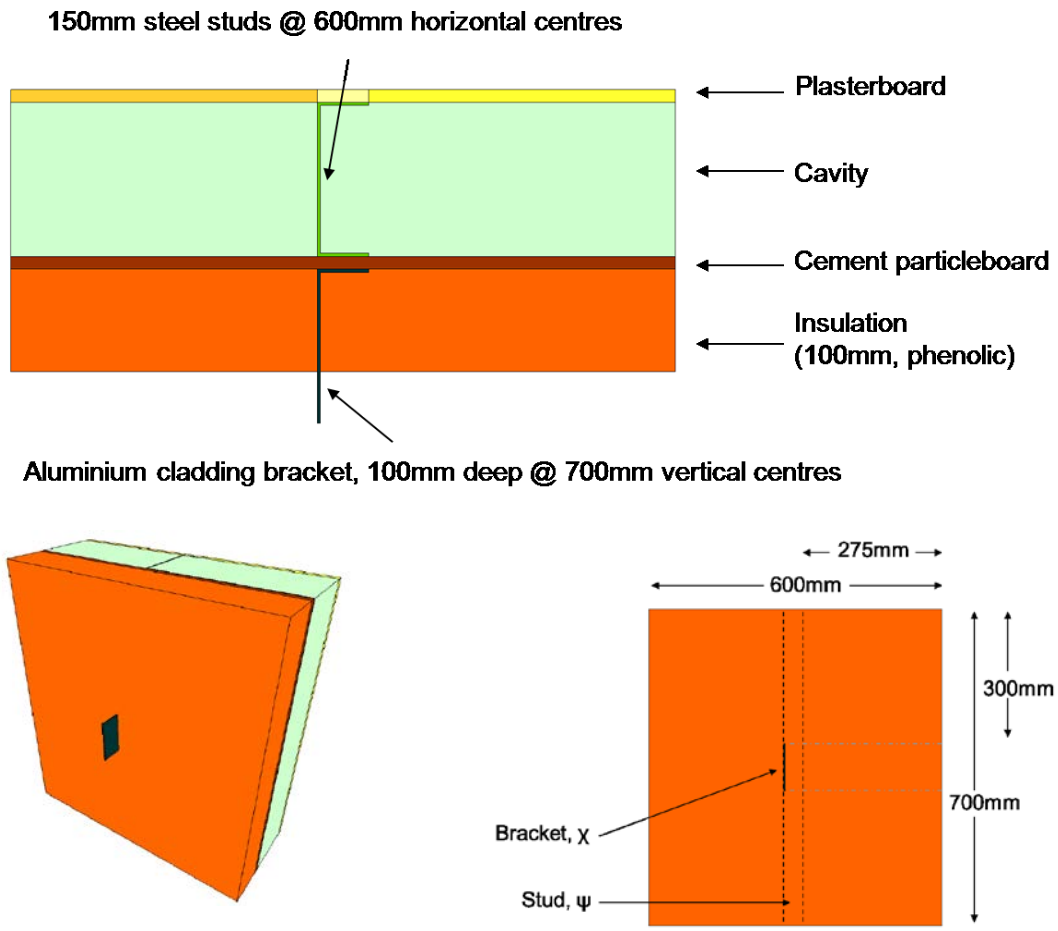


Figure 6.7.4 - Rainscreen system - single assessment method

6.7.6.2 Component assessment method

This method provides a more general method of calculating the overall U-value for a built-up wall. This method involves several simulations in order to calculate the overall U-value of the wall:

- 1D U-value;
- 2D ψ-value (psi);
- 3D χ-value (chi).

Once these values have been found they can be combined in order to calculate the overall U-value of any configuration of those components, i.e. different stud and bracket spacing. This differs from the single assessment method which requires a new simulation whenever the configuration changes.

This method is also useful when looking at the performance of individual components and quantifying the effects of any changes, for example from an aluminium bracket to a stainless steel bracket.

Both 2D and 3D simulations are required for this method. The cut-off planes for the models differ from those for the single assessment method. Rather than being based on the vertical and horizontal centres of the brackets and rails/studs, they are instead set at a minimum of 1000mm for the central element (i.e. the thermal bridge in question), as shown in *Figure 6.7.5*.

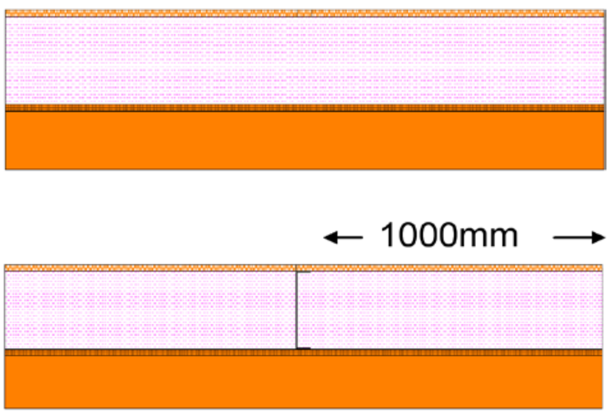
The following equations are used to calculate Ψ and X.

$$\psi = \frac{L^{2D} - U_p.b_b}{b_\psi}$$

- Ψ is the linear thermal transmittance (Ψ-value) of the linear thermal bridge, in W/mK;
- L^{2D} is the 2D thermal coupling coefficient (heat flow from the 2D simulation divided by temperature difference), in W/mK;
- U_p is the 1D U-value of the wall, in W/m^{2}K;
- b_p is the length over which U_p applies (in the 2D model), in m;
- b_ψ is the length of the thermal bridge in the 2D simulation model (1m), in m.

$$\chi = L^{3D} - U_p.b_p - \psi.b_\psi$$

- X is the point thermal transmittance (X-value) of the point thermal bridge, in W/K;
- L^{3D} is the 3D thermal coupling coefficient (heat flow from the 3D simulation divided by temperature difference), in W/K;
- b_p is the length over which U_p applies (in the 3D model), in m;
- b_ψ is the length of the thermal bridge in the 3D simulation model, in m.



1D simulation

2D simulation

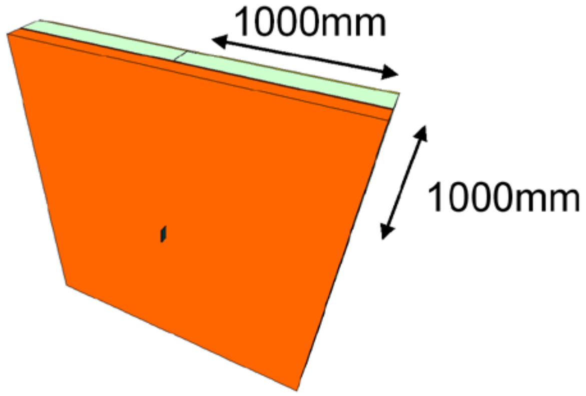


Figure 6.7.5 - Rainscreen assessment - general assessment method

Once Ψ and X have been calculated they can be used together with the 1D U-value of the wall to calculate the overall U-value of wall with any stud and bracket spacing.

$$U_T = \frac{U_p.A_p + \psi.l + \chi}{A_T}$$

- U_T is the overall U-value, in W/m^{2}K;
- A_p is the area over which U_p applies (in the final calculation), in m^2;
- l is the length over which Ψ applies (in the final calculation), in m;
- A_T is the total area (in the final calculation), in m^2.

Using the same wall construction as shown in *Figure 6.7.4*:

- 1D U-value = 0.18 W/m^{2}K;
- Ψ = 0.009405 W/mK;
- X = 0.0481 W/K.

The overall U-value with studs at 600mm horizontal centres and brackets at 700mm vertical centres as before is therefore:

$$U_T = \frac{U_p.A_p + \psi.l + \chi}{A_T} = \frac{0.18 \times 0.55 \times 0.70 + 0.009405 \times 0.7 + 0.0481}{0.60 \times 0.70}$$

- U_T = 0.29 W/m^{2}K as before.

6.7.7 Improving u-values

U-values of built-up walls may be improved in a number of ways, including:

- using greater thicknesses of insulation – there is conflict between the thickness of insulation used and the allowed overall thickness of the wall;
- use insulation with a lower thermal conductivity, such as phenolic foam – there is a potential conflict between thermal performance and fire performance in some cases;
- minimise thermal bridge through appropriate detailing and good site workmanship.

6.7.8 Cavities

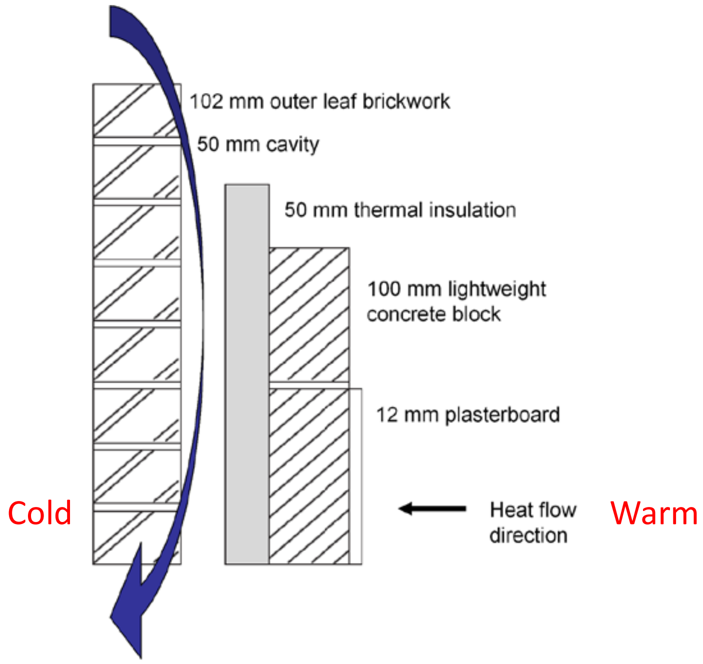
Cavities are integral to most built-up walls as a means of removing moisture, in the form of water vapour moving from the internal environment and liquid water either due to condensation or from water penetration through the external surface. The type of cavity present may affect the U-value of the wall due to the:

- level of ventilation;
- position of insulation in relation to the cavity.

BS EN ISO 6946: 2007 gives cavity definitions and rules for U-value calculations. The results of calculations are given in Sections 6.7.8.1 and 6.7.8.2comparing different cavity ventilation types and insulation positions.

6.7.8.1 Cold cavity construction

This type of air cavity will not change the layered U-value of the construction significantly because the cavity is to the cold side of the main insulation layer (*Figure 6.7.6*).

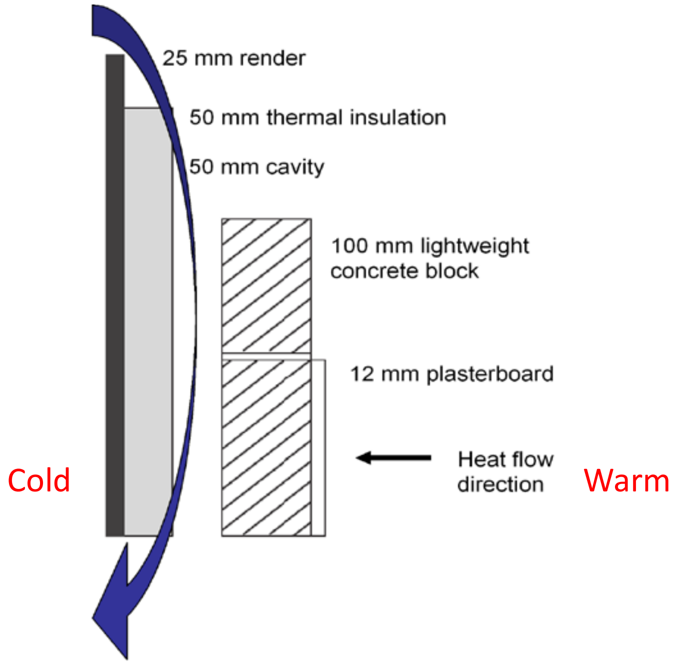


$U_{unventilated}$ = 0.32 W/m^{2}K,
$U_{slightly\ ventilated}$ = 0.33 W/m^{2}K,
$U_{fully\ ventilated}$ = 0.35 W/m^{2}K.

Figure 6.7.6 - Cold cavity construction

6.7.8.2 Warm cavity construction

This type of air cavity will significantly change the layered U-value of the construction (*Figure 6.7.7*). This is because the cavity is to the warm side of the main insulation layer meaning the thermal performance of the insulation layer will be disregarded when the cavity is fully ventilated.



$U_{unventilated} = 0.33\ W/m^2K$,
$U_{slightly\ ventilated} = 0.57\ W/m^2K$,
$U_{fully\ ventilated} = 2.22\ W/m^2K$

Figure 6.7.7 - Warm cavity construction

6.7.9 Interfaces

In addition to the heat transfer through the built-up wall, the extra heat loss that occurs at junctions, interfaces and penetrations must also be taken into account when calculating the overall U-value of the whole façade. Typical interfaces include:

- around windows and doors;
- at the junction between cladding types/systems;
- ground floor;
- roofs;
- floor slabs;
- service penetrations through the wall.

Responsibility for calculating this additional heat loss must be assigned by the main contractor. Calculations will usually be carried out by one of the contractors involved in the interface or by a façade consultant.

Interfaces are discussed in further detail in Chapter 5.

6.8 CONDENSATION

Condensation forms on surfaces that are too cold for the level of water vapour in the air adjacent to them. Condensation may form on surfaces of the building envelope (surface condensation) or within it (interstitial condensation).

Surface condensation has traditionally been an issue on internal surfaces of the building, however external surface condensation is now becoming apparent as building envelopes are better insulated (see Section 6.8.4).

Condensation formation is more readily evident on glazing surfaces but may form on any surface. On non-absorbent surfaces it usually forms into droplets and runs down the surface. On other surfaces it may not form into droplets but be held uniformly spread at the surface of the material.

The condensation risk of a built-up wall depends on a number of factors including:

- level of insulation;
- position of insulation;
- type and position of any vapour control layers;
- internal and external psychrometric conditions (temperature and relative humidity);
- thermal bridging;
- cavity ventilation;
- workmanship.

6.8.1 Building Regulations

Guidance on meeting the requirements for control of condensation in the Building Regulations throughout the various regions of the UK is given in the following documents:

- England: Approved Document C – *Site preparation and resistance to contaminants and moisture*;
- Northern Ireland: Technical Booklet C – *Site preparation and resistance to contaminants and moisture*;
- Scotland: Technical Handbook - Section 3 – *Environment*;
- Wales: Approved Document C – *Site preparation and resistance to contaminants and moisture.*

Approved Documents C give guidance on the resistance to internal surface condensation and mould growth on external walls. An external wall will meet the requirement if:

- ‘it is designed and constructed so that the thermal transmittance (U-value) does not exceed 0.7 W/m2K at any point; and
- the junctions between elements and details of openings, such as doors and windows, are designed to Accredited Construction Details, or follow the guidance of BRE IP 17/01.’

There are no Accredited Construction Details for non-traditional wall construction and therefore it is the responsibility of the designer to ensure that junctions and interfaces are suitably designed and assessed. BRE IP17/01 - *Assessing the effects of thermal bridging at junctions and around openings* is no longer current but is cited in Building Regulations. It has been superseded by BRE IP1/06 - *Assessing the effects of thermal bridging at junctions and around openings.*

Condensation is covered in Technical Booklet C in Northern Ireland. It refers to BS 5250 - *Code of practice for control of condensation in buildings* and BRE Report BR 262, *Thermal insulation: avoiding risks*.

Section C of the Technical Handbook in Scotland again refers to BS 5250 and BRE Report BR 262. In terms of thermal bridging it recommends that the thermal transmittance (U-value) of any part and at any point of the external fabric does not exceed 1.2 W/m^2K, in order to avoid surface condensation.

6.8.2 Specification

A specification may simply state that condensation shall not form on the surface of the wall under standard operating conditions. In addition, condensation shall not form within the wall where it may:

- not be removed by drainage or ventilation;
- impair the thermal insulation;
- lead to rot or corrosion of materials.

This then requires the designer to demonstrate that the proposed design meets the specification (see Section 6.8.3).

6.8.2.1 Normal operating conditions

Condensation formation depends on the internal and external psychrometric conditions which will depend on the usage of the internal space.

Building usage is beyond the control of the Building Envelope Contractor and therefore condensation may occur when the normal operating conditions are exceeded, for example due to insufficient ventilation, or activities such as drying laundry inside.

The designer of the built-up wall should ensure that condensation does not form under normal operating conditions. In the absence of specified psychrometric conditions the values in
Table 6.8.1 and
Table 6.8.2 may be assumed. These values are taken from CWCT *Standard for Systemised Building Envelopes*.

	Temperature	Relative humidity
Summer	+18°C	65%
Winter	-5°C	90%

Table 6.8.1 - External psychrometric conditions

	Temperature	Relative humidity	Minimum internal surface temperature
Houses and flat (low occupancy)	+20°C	55%	10.7°C
Offices	+20°C	40%	6.0°C
Schools	+20°C	50%	9.3°C
Factories and heated warehouses	+15°C	35%	-0.3°C

Table 6.8.2 - Internal psychrometric conditions

In the case of dwellings, the above conditions may be appropriate for the assessment of windows and doors where any condensation which forms will be visible and evident to the building occupants. This may then result in behavioural changes to avoid it occurring in the future.

Condensation forming on the opaque wall area of a dwelling is less obvious, and therefore may cause significant damage to surfaces and materials before it is noticed. Therefore, it is desirable to reduce the risk of condensation forming on opaque surfaces. For this reason, the NHBC specify a higher internal relative humidity of 60 – 70%, which is based on values from Table D7: BS 5250 for dwellings with high occupancy.

It should be noted that higher humidities are generated in kitchens, bathrooms and laundries, where different conditions may apply unless additional ventilation is provided. The Specifier shall identify any zones of abnormally high relative humidity.

6.8.2.2 Thermal bridging

Particular attention should be given to limiting thermal bridges. This is a requirement of the various Building Regulations in the UK (e.g. Part L in England). Thermal bridges are a major cause of condensation (both surface and interstitial) due to the effect they have on the temperature distribution through the wall.

Thermal bridges may occur within the wall or at an interface or junction, such as that with a window or door, *Figure 6.8.1.*

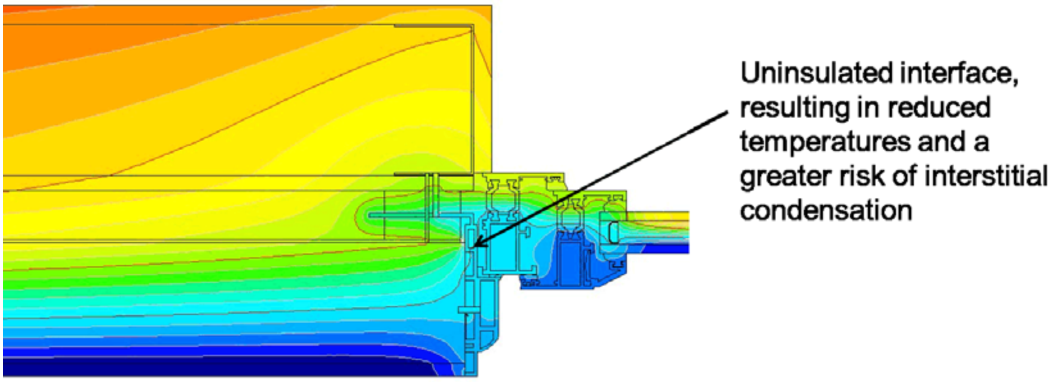


Figure 6.8.1 - Thermal bridging at a window interface

6.8.3 Condensation risk analysis

The type of analysis required will generally depend upon:

- the complexity of the wall;
- the type of condensation to be assessed - surface or interstitial.

Plane, layered elements may be assessed by the methodology set out in the Standards listed below. Complex walls will require computer analysis. Continuous (linear) elements such as rails and studs may be assessed using two-dimensional analysis, whereas discrete (point) components such as local brackets require three-dimensional analysis in order to accurately assess the temperature and moisture condition within the wall.

6.8.3.1 BS 5250: 2011 - Code of practice for control of condensation in buildings

This British Standard gives recommendations and guidance on avoiding problems with high moisture levels and condensation in buildings. Recommendations given are based on forms of construction commonly adopted in the UK.

To assess the likelihood of condensation, BS 5250 directs the reader to the methods described in BS EN ISO 13788.

6.8.3.2 BS EN ISO 13788:2012 - Hygrothermal performance of building components and building elements. Internal surface temperature to avoid critical surface humidity and interstitial condensation. Calculation methods

This Standard gives calculation methods for:

- the internal surface temperature of a building component or building element below which mould growth is likely, given the internal temperature and relative humidity – the method can also be used to assess the risk of other surface condensation problems;
- the assessment of the risk of interstitial condensation due to water vapour diffusion.

The interstitial condensation risk analysis consists of an annual moisture balance calculation, whereby the condensation accumulated during the winter months is compared with the total evaporation during the rest of the year.

The calculation method given in this standard is a simplified steady-state method also known as the Glaser method and assumes that moisture movement is by vapour diffusion alone. The limitations of this calculation method can give rise to designs which are on the safe side especially where other moisture sources, e.g. rain penetration or convection are negligible This gives results which are more reliable for a built-up wall that is lightweight and airtight than for one that is not airtight and/or contains materials with large water storage capability.

In the latter case or where a built-up wall is calculated to be at risk of condensation using this method then a more accurate dynamic or transient computerised calculation method could be considered for the condensation risk analysis.

6.8.3.3 BS EN 15026:2007 - Hygrothermal performance of building components and building elements. Assessment of moisture transfer by numerical simulation

This standard specifies a set of equations to be used in hygrothermal simulation software (e.g. WUFI) for predicting transient heat and moisture transfer in non-steady climatic conditions. The standard also provides a benchmark example and tolerances to allow validation of software which claims conformity with the standard.

Although this simulation method can provide a more accurate prediction of hygrothermal performance of a multi-layered construction there is also the requirement for a greater level of detailed information on the materials, building operation, orientation, climatic conditions etc., than the steady-state method in BS EN ISO 13788 and will usually require specialist expertise to undertake the analysis. The appropriateness and benefit of adopting this approach would need to be considered against the increased time, effort and potential cost that it would entail.

6.8.3.4 Complex analysis

The Standards described above provide methods of one-dimensional calculation for plane, layered constructions and may be referred to in the first instance.

Complex two-dimensional (e.g. support rails) and three-dimensional (e.g. brackets and fixings) constructions require a thermal and vapour simulation to accurately assess the risk of surface and interstitial condensation.

6.8.3.4.1 Complex analysis – surface condensation

The output of most thermal analysis programmes includes the temperature factor at the minimum internal surface temperature, f_{Rsi}. The temperature factor is defined as:

$$f_{Rsi} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e}$$

Where:

- θ_I is the internal air temperature in °C;
- θ_e is the external air temperature in °C;
- θ_{si} is the temperature of the internal surface in °C.

This allows for calculation of the minimum internal surface temperature which can be compared with the dew point temperature for the specified internal psychrometric conditions. For example, given:

- f_{Rsi} = 0.75;
- θ_I = 20°C;
- θ_e = 0°C;

The minimum internal surface temperature is:

- θ_{si} = 15°C.

This can then be compared with the allowable values given in
Table 6.8.2, or for any other internal conditions.

6.8.3.4.2 Complex analysis – interstitial condensation risk

Interstitial condensation of a complex detail is more involved and requires both thermal and vapour transfer analyses of the wall. The methodology involves;

- Calculating the saturated vapour pressure (SVP) at points through the wall, from a thermal analysis
- Carrying out a vapour transfer analysis to establish the vapour pressure (VP) at points through the wall,
- Comparing VP and SVP at each point.

In order for there not to be a condensation risk the VP should be less than the SVP at all points.

Software designed for thermal analysis, such as BISCO and TRISCO can also be used for vapour transfer analysis, by making the following substitutions;

- µ, the water vapour resistance factor, in place of λ, the thermal conductivity,
- p_i and p_e, the internal and external vapour pressure in place of θ_I and θ_e, the internal and external temperature.

Values of µ may be obtained from BS EN 12524 - *Building materials and products. Hygrothermal properties. Tabulated design values* or determined in accordance with BS EN ISO 12572 - *Hygrothermal performance of building materials and products. Determination of water vapour transmission properties*.

p_i and p_e may be obtained from knowledge of the temperature and relative humidity of the internal and external air.

Specific software designed for the assessment of condensation risk is also available.

The following outputs are from a series of analyses undertaken using the thermal analysis software TRISCO. The analyses have been carried out under UK/EN environmental conditions with higher temperatures and vapour pressures internally.

Figure 6.8.3 and *Figure 6.8.4* show the temperature distribution and vapour pressure distribution of the wall build-up shown in *Figure 6.8.2*.

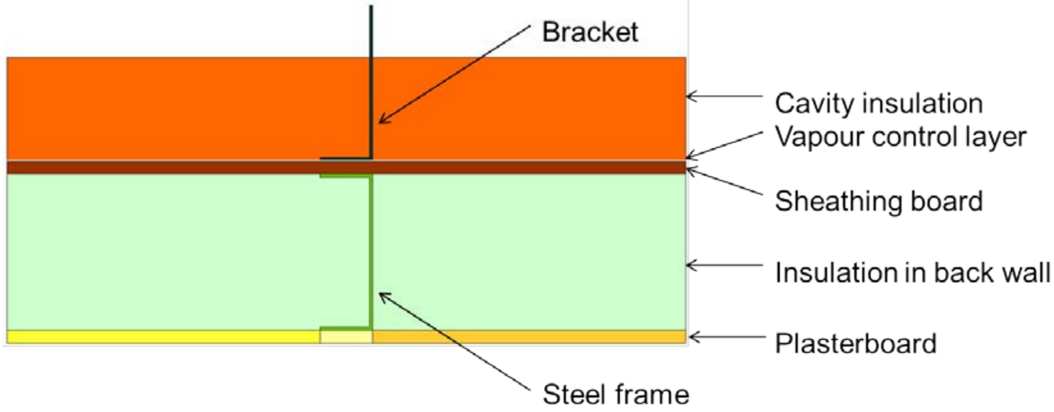


Figure 6.8.2 - Wall build-up

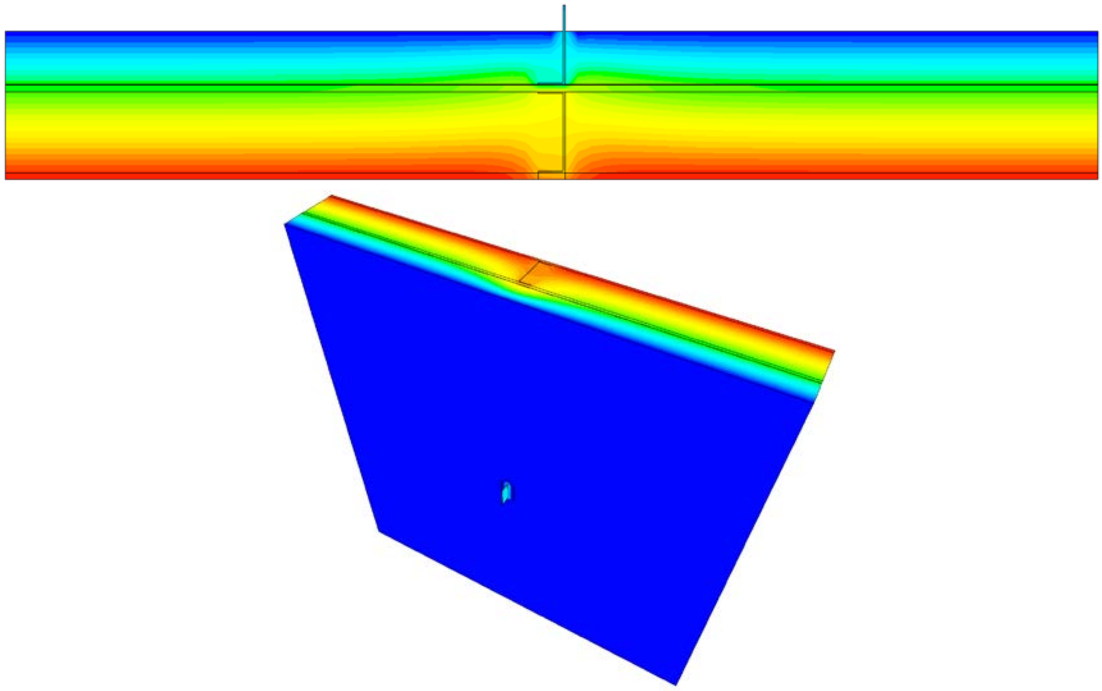
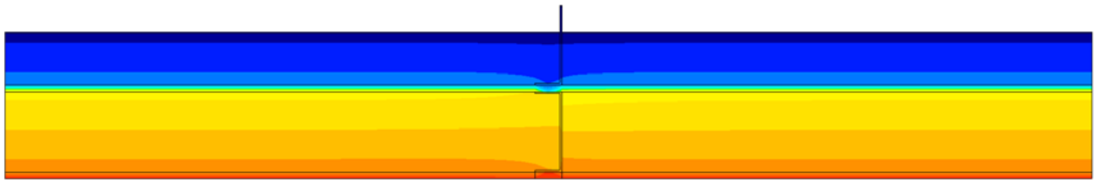


Figure 6.8.3 - Temperature distribution



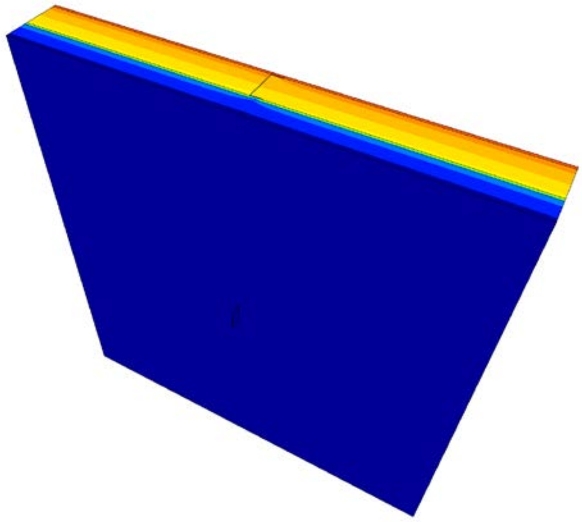


Figure 6.8.4 - Vapour pressure distribution

Figure 6.8.5 shows the vapour pressure excess, i.e. areas where the local vapour pressure is greater than the saturated vapour pressure at that point. These are the areas that will experience condensation under the design conditions.

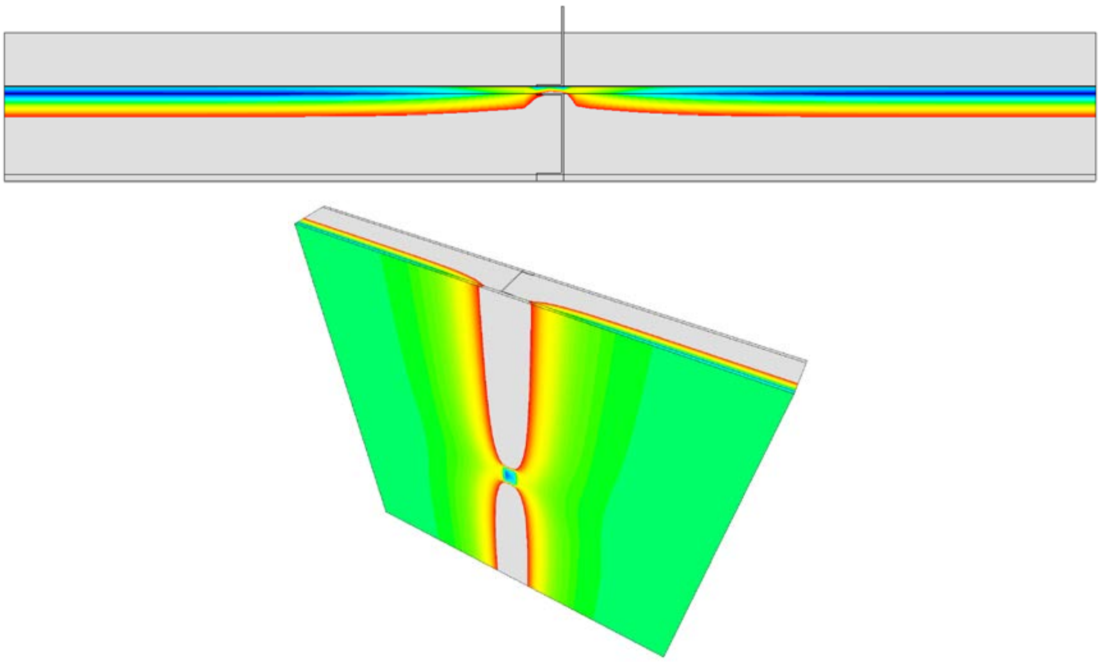


Figure 6.8.5 - Vapour pressure excess

6.8.3.5 Insulation position

The position of insulation within the built-up wall is very important in terms of the formation of interstitial condensation. In UK-type climates where the internal moisture levels are higher than those externally, placing the insulation as close to the cold side of the wall as possible reduces the risk of interstitial condensation. *Figure 6.8.6* shows a built-up wall with no insulation between the studs of the steel framed backing wall. This results in the majority of the wall being warm.

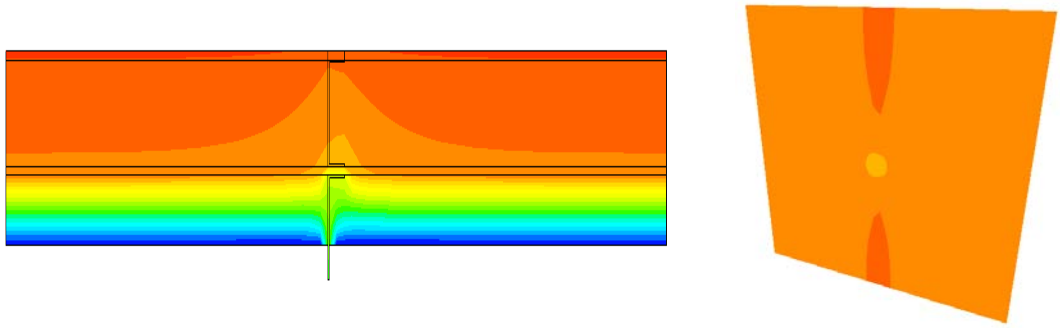


Figure 6.8.6 - Temperature distribution through the wall and on the cold side of the sheathing board without insulation between the studs

Figure 6.8.7 shows the temperature distribution of a built-up wall which has insulation between the studs of the backing wall. The insulation close to the warm side of the wall has significantly altered the temperature distribution, making the majority of the wall much cooler than that shown in *Figure 6.8.6* (the minimum temperature of the sheathing is 8.1°C compared to 16.3°C). This in turn will increase the probability of the temperature being below the dew point temperature and therefore increase the risk of interstitial condensation.

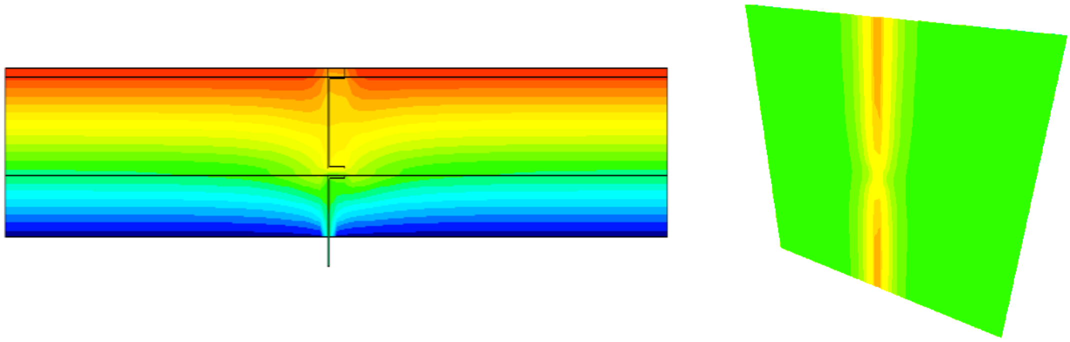


Figure 6.8.7 - Temperature distribution through the wall and on the cold side of the sheathing board with insulation between the studs

Due to ever tighter U-value requirements it is often necessary to place insulation between the studs as shown above or have insulation between the studs as well as thin layer of insulation in the cavity. Care should be taken to avoid the risk of condensation under such circumstances, particularly where there is a vapour control layer within the built-up wall (see Section 6.8.3.6) and the position of the dew point is unknown. A condensation risk analysis should be carried out and the responsibility for preparing it should ideally be assigned to the most appropriate party especially where there is the potential of divided responsibilities between different subcontractors.

6.8.3.6 Vapour control layers and breather membranes

An appropriately selected, detailed and installed vapour control layer can reduce the risk of interstitial condensation in a built-up wall. An incorrectly specified and installed vapour control layer however may increase the risk of interstitial condensation.

Particular attention should be paid to situations where there is insulation between the studs of the backing wall and consideration is being given to positioning a vapour control layer on the cold side of the sheathing boards. The vapour control layer in that position would unduly restrict the passage of any water vapour through the wall, leading to potentially high moisture levels. When combined with the reduced temperatures at this location due to the insulation between the studs, the risk of condensation is greatly increased. In such situations a breather membrane in place of the VCL on the cold side of the sheathing may be more appropriate (if the dew point position is between the studs) as this will allow moisture vapour to diffuse through the wall whilst still providing protection against liquid water ingress from the external environment.

Vapour control layers should be placed on the warm side of the dew point of the wall and breather membranes usually positioned to the cold side of the dew point of the wall. In certain circumstances the use of an 'intelligent' membrane may be suitable for either dew point position. Vapour control layers and breather membranes are discussed in further detail in Sections 4.1.2 and 0.

Any imperfections in the vapour control layer could result in a significant reduction in its performance/effectiveness. The better the vapour control layer (the higher its vapour resistance) the more significant any holes become (see Section 6.8.3.6.1).

This is analogous to thermal bridging where heat transfer in parallel occurs (i.e. two different heat flow paths). In the case of an imperfect vapour control layer, moisture will either transfer through the material (the VCL) or through the imperfections, which can be treated as if they are still air. The formula for calculating the overall vapour resistance of imperfect VCL is therefore:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

Where:

- R_T is the total vapour resistance, in MNs/g;
- R_1 is the vapour resistance of the material (the vapour control layer), in MNs/g;
- R_2 is the vapour resistance of air (i.e. the imperfection in the VCL), in MNs/g.

If the vapour control layer is positioned immediately behind internal wall finishes (e.g. plasterboard), building occupants may inadvertently damage vapour control layers by actions such as attaching shelves/cupboards to the wall, or by fitting new electrical sockets etc. An O&M manual should be provided and any work carried out should be done following the guidance given.

6.8.3.6.1 Imperfect VCL example calculation

The situation shown in *Figure 6.8.8*, two sheets of plasterboard with a 2mm gap between them, is used to illustrate the effect on the vapour resistance of a layer which is imperfect.

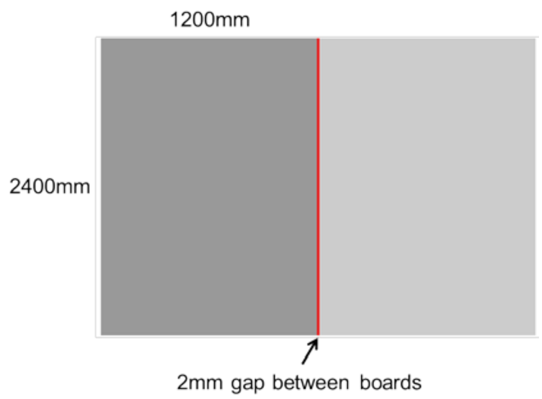


Figure 6.8.8 – Effect of gap between vapour control plasterboards

Two cases are calculated:

- 12.5mm plasterboard with a metallised polyester foil laminated onto the back ('vapour check' plasterboard), with a vapour resistance of 78.5 MNs/g;

- 12.5mm standard plasterboard, with a vapour resistance of 0.75 MNs/g.

The vapour resistivity of still air is taken as 5 MNs/gm, as given in BS 5250. A 12.5mm thick air layer therefore has a vapour resistance of 0.0625 MNs/g.

The total area of Figure 6.8.8 is 5.76m^2. The area of the gap between the boards is 0.0048m^2. This represents 0.083% of the total area.

Case 1:

$$\frac{1}{R_T} = \frac{0.99917}{78.5} + \frac{0.00083}{0.0625} = 0.026\,g/MNs$$

R_T = 38.45 MNs/g.

Case 2:

$$\frac{1}{R_T} = \frac{0.99917}{0.75} + \frac{0.00083}{0.0625} = 1.465\,g/MNs$$

R_T = 0.68 MNs/g.

This calculation illustrates that the higher the vapour resistance of a material, the more significant any defects are. For the case with the vapour check plasterboard the 2mm gap reduced the overall vapour resistance to 49% of the value of vapour check plasterboard alone. With standard plasterboard the 2mm gap reduced the overall vapour resistance to 91% of the material value.

This illustrates the importance of correct sealing and detailing of layers/materials which are intended to act as a vapour control layer. Where this involves taped joints, such as those between plasterboard or insulation boards it is crucial to the long term performance of the joint that the correct tape is used. In reality the cheapest tape is often used with little regard to how this will perform over time.

6.8.4 External surface condensation

As building envelopes become more highly insulated the risk of condensation on the external surface increases. External condensation occurs on cold mornings when the external surface temperature falls below ambient due to radiation losses to a clear night sky. An example is shown in *Figure 6.8.9*.

Figure 6.8.9 - External condensation

In poorly insulated buildings external condensation was not an issue as heat loss through the building envelope warmed the external surface above the dew point temperature. Building Regulations are now requiring increasing levels of insulation, which reduces the heat loss through the façade, which is good for energy efficiency. The downside is that the external surface of the building is cooler and therefore external condensation more likely to form. External condensation is an indication of good thermal performance and is a feature we have to recognise and live with and it should not be considered a defect.

There are a number of issues with external condensation including;

- Visual problem on the glass;
- Deposition of dirt;
- Requirement for more cleaning;

Framing members, panel stiffeners and brackets create warmer patches on the external surface of the wall which may show as a pattern amongst any condensation and lead to long term pattern staining.

External condensation may form on the outer surface of an externally insulated render system and on both sides of a rainscreen panel. In the short term external condensation is unlikely to be noticeable on externally insulated render, however may lead to long term staining. Special self-cleaning renders are available that will minimise the build-up of dirt.

6.9 ACOUSTICS

There are two aspects of acoustic performance that the façade designer/specifier must consider. These are:

- direct transmission through the wall;
- flanking transmission between internal spaces.

6.9.1 Direct transmission

For many situations a 'standard' wall construction will provide adequate sound insulation in terms of direct transmission. Where the requirements are more onerous, such as where the external environment is particularly noisy, or where a very low internal sound level is specified, additional measures may have to be taken. In addition to improving the performance of the façade, other measures may be taken to reduce the internal sound level including:

- acoustic treatment of internal surfaces;
- orientation of the building to minimise exposure to the noise source;
- screens/external obstructions to shield the façade from the noise source;
- careful planning of the internal layout to ensure noise sensitive-spaces are away from vulnerable areas.

The acoustic performance of a built-up wall is a function of:

- mass;
- stiffness;
- isolation;
- sealing.

Additional factors such as the area of window openings will also influence the overall acoustic performance of the zone.

Sound transmission across a solid wall obeys a **mass law**, which states that the sound insulation of a solid element will increase by approximately 5dB per doubling of mass. For this reason, built-up walls with a masonry backing wall tend to perform better than those on lightweight metal or timber studs. Other features which will help to improve the performance by increasing the mass include:

- dense acoustic mineral wool in the insulation cavity;
- a dense sheathing board such as cement particle board.

The **stiffness** of the wall is also important in terms of its acoustic performance. Stiffer walls deflect less due to incident sound pressure waves and therefore have a better sound reduction index for airborne noise transmission. This is particularly true for low frequency sound transmission, such as that due to urban road traffic.

Lightweight framed walls achieve far better performance than the mass law states due the presence of a cavity and therefore a degree of **isolation** between the various layers of the construction. Any brackets, rails or studs which bridge the cavity will limit the performance. Best performance would be achieved with separate staggered studs for each face of the backing wall.

Effective **sealing** of a wall is vital if the designed acoustic performance is to be met. Any gaps or holes within the wall or at interfaces with other elements such as windows will provide a means for the sound to 'bypass' the wall. This requires appropriate interface design and detailing to ensure that openings and penetrations are properly sealed, see Chapter 5.

Due to the lightweight nature of rainscreens/EWIS on framed backing walls, they are often not the most suitable where the airborne sound insulation requirements are particularly onerous, such as sites near to railways or airports. Where the use of a lightweight wall is proposed in such situations, it is vital that early guidance is sought on the appropriateness of the solution and the scope investigated for improving the acoustic performance of the backing wall by measures that may include introduction of high density acoustic insulation in addition to (not instead of) the thermal insulation required.

6.9.2 Flanking transmission

Flanking transmission is sound transmission between two areas by indirect paths, particularly around dividing walls and floors. Therefore, the detailing between the internal lining of the built-up wall and the partition wall/floor slab is crucial in minimising flanking transmission.

Flanking transmission is of particular concern in buildings with multiple occupants, especially domestic buildings, where such transmission may cause serious disturbance.

6.9.3 Acoustic performance

The acoustic performance of a built-up wall can be described by the:

- sound reduction index (SRI);
- sound insulation;
- sound difference level;
- sound transmission.

These terms effectively describe the same thing, i.e. how much of the direct sound transmission the wall cuts out.

The acoustic performance of a wall is frequency dependent. Porous absorbers, such as mineral wool perform better at mid to high frequencies, whereas panel absorbers, such as a board material in front of a cavity, work better at low frequencies.

Most sounds are made up of a range of frequencies, with the ear being sensitive to those from approximately 20 to 20000Hz. Rather than measuring the sound level at each individual frequency, frequency bands are used. These may be either octave bands (where the highest frequency is double the lowest frequency), or one-third octave bands. These are more accurate but require more data than the use of full octave values. The acoustic performance of a wall may be measured in the same way

6.9.3.1 Sound weighting

The human ear is not equally sensitive to all frequencies. The ear is most sensitive at mid-range frequencies (between 1 – 4 kHz) and less so at higher and lower frequencies. When measuring sound, it is useful to weight the different frequencies so that those having greatest impact on the ear are given a greater weighting. The A-weighting spectrum is used to describe the human response to sound, see *Figure 6.9.1*.

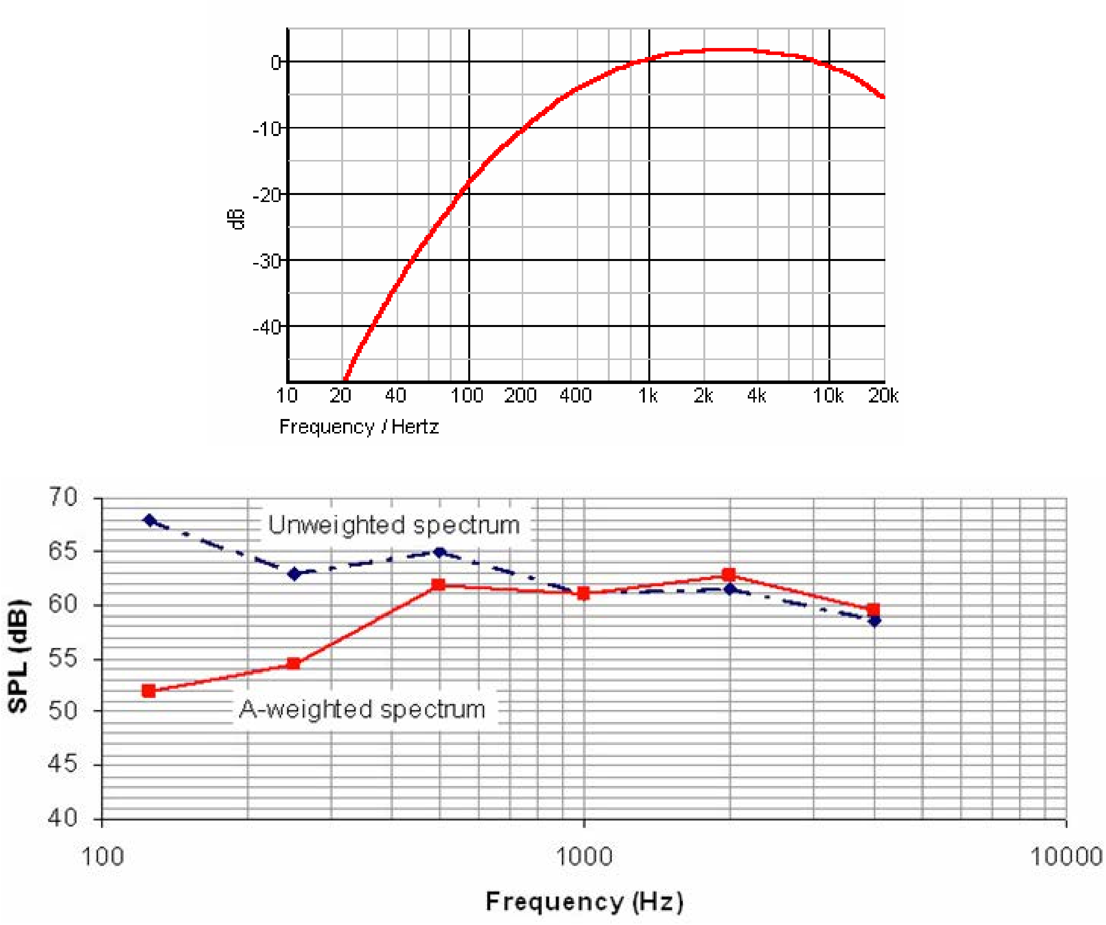


Figure 6.9.1 - A-weighting correction curve (top), Weighted and unweighted sound spectrum (bottom)

A sound pressure level which has been A-weighted will have units of dBA, or dB(A).

6.9.3.2 Flanking transmission

Flanking transmission is noise from a source room that is not transmitted via the separating element. Instead it is transmitted indirectly via paths such as external walls and internal corridors, see *Figure 6.9.2*.

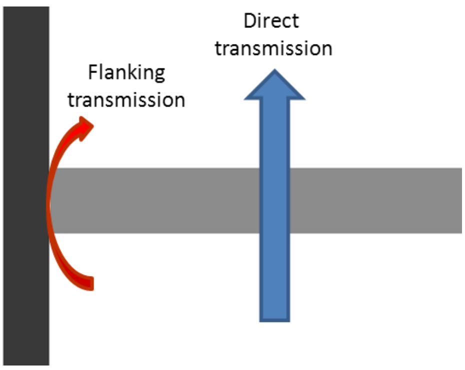


Figure 6.9.2 - Flanking transmission between a built-up wall and a floor slab

It is vital that flanking transmission is considered at the design stage and that construction detailing at interfaces (both horizontal between rooms on the same floor, and vertical between floors) is specified so as to eliminate or at least minimise its effect. Workmanship is also a key issue and it is vital that all products are installed correctly.

6.9.4 Building Regulations

Guidance on meeting the requirements for acoustic performance in the Building Regulations throughout the various regions of the UK is given in the following documents:

- England: Approved Document E – *Resistance to the passage of sound*;
- Northern Ireland: Technical Booklet G – *Resistance to the passage of sound*;
- Scotland: Technical Handbook - Section 5 – *Noise*;
- Wales: Approved Document E – *Resistance to the passage of sound.*

Approved Document E (AD E) in both England and Wales applies to:

- dwelling-houses and flats;
- rooms for residential purposes:
  - hotel rooms,
  - student accommodation,
  - etc.

AD E is not concerned with noise from outside the building so does not give minimum SRI requirements for external walls. It instead states that dwelling-houses, flats and rooms for residential purposes shall be designed and constructed in such a way that they provide reasonable resistance to sound from other parts of the same building and from adjoining buildings. The requirements of AD E are met by meeting minimum values of airborne sound insulation and impact sound insulation for separating walls and floors. In addition, flanking transmission (horizontal and vertical) must also be considered and its effects minimised.

Compliance may be demonstrated by:

- pre-completion testing;
- using design details approved by Robust Details Ltd.

There are no robust details given for built-up walls

Technical Handbook – Section 5 in Scotland and Technical Booklet G in Northern Ireland are broadly in line with those described above.

6.9.5 Schools

Acoustic performance requirements for schools are set out in Building Bulletin 93 – *Acoustic design of schools: performance standards* (BB93). These requirements can be met by following the guidance in *Acoustics of Schools: a design guide* jointly published by the Association of Noise Consultants (ANC) and the Institute of Acoustics (IOA).

The requirements set out in BB93 cover:

- indoor ambient noise levels in unoccupied spaces;
- airborne sound insulation between spaces;
- airborne sound insulation between circulation spaces and other spaces used by students;
- impact sound insulation of floors;
- reverberation in teaching and study spaces;
- reverberation and acoustic absorption in sports halls and swimming pools;
- sound absorption in corridors and stairwells;
- open plan teaching and learning.

Table 1 of BB93 gives the upper limit for the indoor ambient noise level for different situations for both new build and refurbishment projects. Tables 3a and 3b gives the minimum airborne sound insulation required between spaces based on the noise tolerance in the receiving room and the activity noise in the source room for new build and refurbishment projects respectively.

Acoustics of Schools: a design guide gives the acoustic performance of typical partition walls but offers very limited advice for external walls other than that performance can be determined by testing to BS EN ISO 10140-2 – *Acoustics, Laboratory measurement of sound insulation of building elements, Measurement of airborne sound insulation.*

6.9.6 Specification

The overall sound level in a room depends on a number of factors including:

- the external sound level;
- the sound reduction index of the façade;
- the size and geometry of the room behind the façade;
- the treatment of surfaces within the space.

The envelope contractor cannot therefore be responsible for delivering a particular internal sound level. For a particular internal sound level the specifier should assess the possible solutions and state the contribution required by the façade.

The external sound reduction performance of the built-up wall should usually be specified using a single number weighted sound reduction index (SRI), R_w, as defined in BS EN ISO 717-1:2013 – *Acoustics, Rating of sound insulation in buildings and of building elements*. If required spectrum adaptation terms may also be added e.g. C_{tr} is used where road traffic noise is the source signal.

In addition, the SRI at specific frequency bands, either full or one-third octave, may also be specified. This is to ensure that the wall construction performs adequately over a particular range of frequencies which may be associated with a particular external acoustic environment.

Key components which will have a significant influence on the acoustic performance of a built-up wall include:

- sheathing boards;
- insulation material.

The sheathing boards add mass to the wall. A thicker sheathing board than would otherwise be required based on the structural performance may be specified in order to improve the acoustic performance.

Due to its porous nature mineral wool insulation is a good acoustic absorber and may be specified for its acoustic performance. Different densities are available with the acoustic performance generally improving with the increase in density. The thermal conductivity of mineral wool is higher than other insulation materials such as phenolic/PIR/PUR and therefore a greater thickness will be required for a given thermal performance. It is not uncommon to use different insulants within a wall build-up to achieve the required thermal and acoustic performance.

Due to the contractual nature of most built-up walls, there is no single point of responsibility for the overall design (see Chapter 2). It is therefore vital that such layers/components are explicitly specified and are not substituted for alternative products, for example thinner/less dense cement particle boards, or foam insulation instead of mineral wool.

The acoustic specification may include SRIs for the:

- built-up wall only;

- complete façade (wall and windows);
- windows only.

The SRI index of a composite wall (containing opaque wall and windows) may be obtained following the procedure set up in BS 8233 - *Guidance on sound insulation and noise reduction for buildings.*

It is generally recognised that if the SRI of the opaque wall is 15dB greater than that of the windows, the windows dominate the performance such that the acoustic performance of the wall can be ignored.

6.9.7 Standards and guidance

There are a number of Standards dealing with acoustics of building envelopes.

Further information on building envelope acoustics may also be found in the following CWCT Technical Notes:

- TN37 - *Introduction to building envelope acoustics*;
- TN38 - *Acoustic performance of windows*;
- TN39 - *Sound transmission through building envelopes*;
- TN40 - *Sound environment behind a building envelope*.

6.9.7.1 BS EN ISO 10140 - Acoustics – Laboratory measurements of sound insulation in building elements

This Standard is split into five parts covering various measurements of sound insulation.

Perhaps of most significance to built-up walls is Part 2: *Measurement of airborne sound insulation*. This deals with laboratory testing of acoustic performance.

The test element is mounted in an opening in a partition between two rooms (one being designated the source room and the other the receiving room). A diffuse sound field is generated in the source room and the average sound pressure levels are then measured in the source and receiving rooms, normally in the frequency range of 100 Hz to 5 000 Hz although it is not uncommon for lower frequencies to be included in the test. From this, the sound reduction index (SRI) can be calculated.

For the statement of the airborne sound insulation of the test element, the measurement results shall be given in decibels at all measurement frequencies in one-third octave bands to one decimal place, both in tabular form and in the form of a curve.

BS EN ISO 10140-2 has replaced BS EN ISO 140-3.

6.9.7.2 BS EN ISO 717-1 - Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation.

BS EN ISO 717-1 gives a standardised method whereby the frequency-dependent values of airborne sound insulation can be converted into a single number characterising the acoustical performance.

This Standard gives rules for determining a single number quantity for the airborne sound insulation of a building element (wall, floor, door, and window) from the results of measurements carried out according to BS EN ISO 10140 as described in Section 6.9.7.1. In addition, it takes into consideration the different sound level spectra of various noise sources such as noise sources inside a building and traffic outside a building.

In order to obtain a single number rating a set of noise reduction values at the sixteen third-octave bands from 100 to 3150 Hz from a BS EN ISO 10140 test are plotted on a standard chart and overlaid with a reference curve. The reference curve is then adjusted up or down so that the sum of the unfavourable deviations (where the measured sound reduction index is less than the reference value is at that point) is less than or equal to 32 dB. The new value of the reference curve at 500Hz gives the weighted sound reduction, R_w rating. This is shown in *Figure 6.9.3* where R_w for this set of data is equal to 30 dB.

BS EN ISO 717-1 also allows for sound reduction figures to be compensated allowing for different source types:

- C is the adaptation term for A-weighted pink noise:
  - Living activities,
  - Railway traffic at medium and high speed,
  - Road traffic >80 km/h,
  - Jet aircraft, short distance,
  - Factories emitting medium and high frequency noise;

- C_{tr} is the adaptation term for A-weighted traffic noise:
  - Railway traffic at low speed,
  - Urban road traffic,
  - Aircraft, propeller driven, or jet aircraft, long distance,
  - Disco music,
  - Factories emitting low and medium frequency noise.

As before the terms C and C_{tr} are calculated by comparing the results of test data with reference curves.

The final results of single number weighting and adaptation terms are expressed in the following way:

- R_w (C; C_{tr}) = 41 (-2; -5) dB

In the above example:

- R_w = 41 dB;
- R_w + C = 39 dB;
- R_w + C_{tr} = 36 dB

	one-third octave	reference values	unfavourable deviations	reference values - 22 dB	unfavourable deviations
100	20.4	33.0	12.6	11.0	0.0
125	16.3	36.0	19.7	14.0	0.0
160	17.7	39.0	21.3	17.0	0.0
200	22.6	42.0	19.4	20.0	0.0
250	22.4	45.0	22.6	23.0	0.6
315	22.7	48.0	25.3	26.0	3.3
400	24.8	51.0	26.2	29.0	4.2
500	26.6	52.0	25.4	30.0	3.4
630	28.0	53.0	25.0	31.0	3.0
800	30.5	54.0	23.5	32.0	1.5
1000	31.8	55.0	23.2	33.0	1.2
1250	32.5	56.0	23.5	34.0	1.5
1600	33.4	56.0	22.6	34.0	0.6
2000	33.0	56.0	23.0	34.0	1.0
2500	31.0	56.0	25.0	34.0	3.0
3150	25.5	56.0	30.5	34.0	8.5
sum			368.8		31.8
adjustment			22.0		

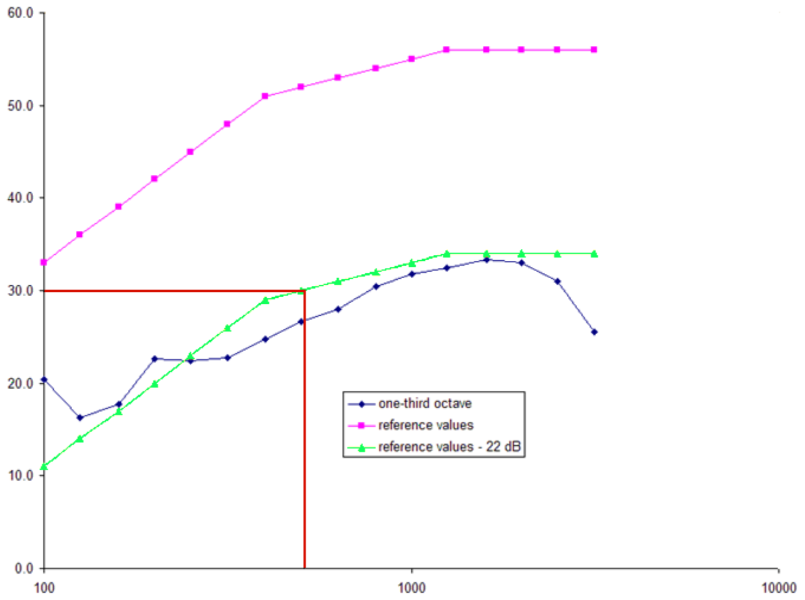


Figure 6.9.3 - Single number sound reduction

6.9.7.3 BS 8233 – Guidance on sound insulation and noise reduction for buildings

This British Standard gives recommendations for the control of noise in and around buildings, and suggests appropriate criteria and limits for different situations. These criteria and limits are primarily intended to guide the design of new or refurbished buildings undergoing a change of use, rather than to assess the effect of changes in the external noise level.

The Standard also allows calculation of the overall sound insulation of a partition consisting of two parts having different sound-insulating properties, for example a window in a wall. It may also be used to give an indication of the effect of gaps or holes in a partition by assigning a sound insulation value of 0 dB to the aperture.

The combined sound insulation depends on the:

- relative areas of the different elements;
- difference in acoustic performance between the elements.

Based on these values the combined sound insulation may be found by using the chart shown in *Figure 6.9.4*. An example of its use is shown below based on the data in *Figure 6.9.5*.

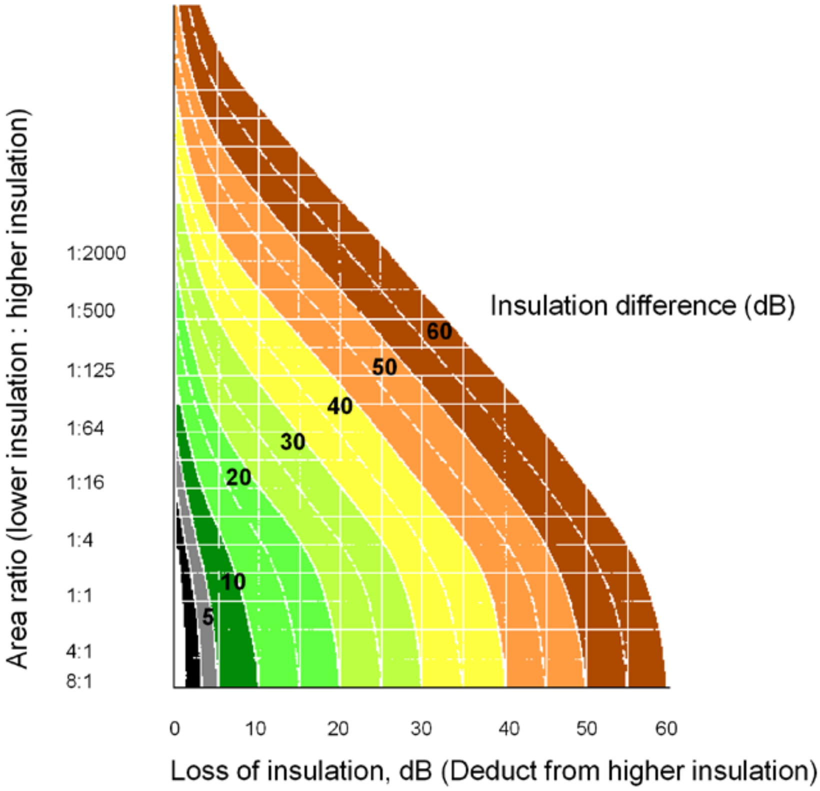


Figure 6.9.4 - Sound insulation of non-uniform partitions

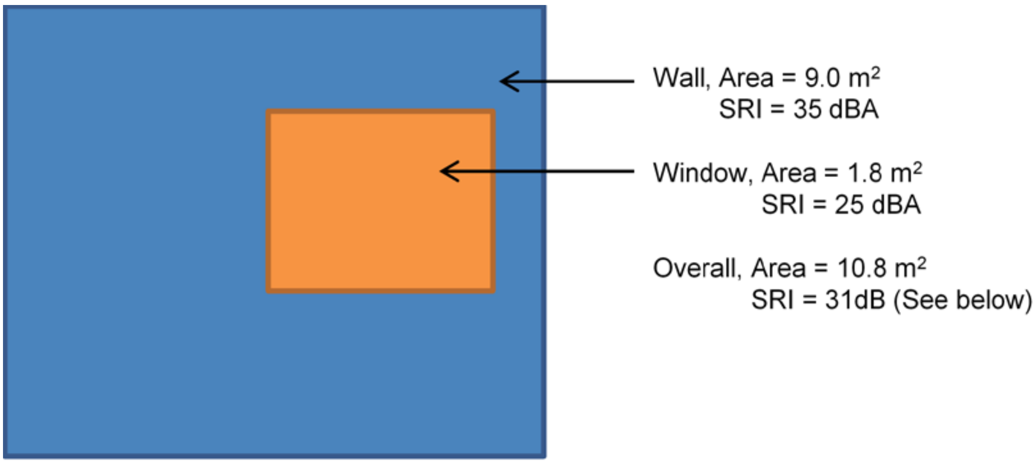


Figure 6.9.5 - Composite sound insulation - example calculation

- difference in SRI of 10 dBA (35 – 25);
- area ratio = 1:5;
- from *Figure 6.9.4*, deduct 4 dBA from the higher insulation;
- overall SRI = 31 dBA.

It should be noted that the above result would only be achieved if the interface/sealing around the window was adequate. Any gaps around the window will result in a significant reduction in the overall sound insulation of the partition.

7 DURABILITY

7.1 Introduction

Durability is the ability of a material or component to provide acceptable performance for a period of time. Some materials are inherently durable and will give a long life with minimal maintenance, others will require regular maintenance to maintain performance and yet others will have limited life even with appropriate maintenance.

It is possible to construct built-up walls that will give a long life with minimal maintenance but this will limit the materials and details that can be used. It may be preferable to use less durable materials and accept the need for periodic replacement.

A coordinated approach is required to ensure that the durability of the façade is not compromised by the incorporation of components with a shorter life than others.

The built-up wall needs to have an acceptable performance throughout its life. This will not be the as-new performance and the wall will deteriorate during its life. This deterioration should be taken into account during the design of the wall in order to ensure the performance remains at an acceptable level throughout its life. In many cases the appearance of the wall will be the factor which determines whether or not the wall is acceptable.

Where a façade contains components that will need maintenance or replacement it is important that the façade is designed and constructed in such a way that maintenance and replacement can be carried out without compromising the performance of the rest of the façade.

The overall durability of a built-up wall will depend on numerous factors, including:

- materials used;
- façade design and detailing;
- maintenance strategy;
- climate/environmental conditions.

It should be noted that the design life of the envelope system need not be the same as the design life of the building which it encloses. Some envelope systems have a forecast service life in excess of fifty years provided that they are properly maintained. Other systems may not be able to provide this degree of longevity. Replacement of the built-up wall at the end of its life is easier in a building with a single occupier. In buildings of multiple occupancy such as apartments, agreeing on a replacement strategy may be very difficult.

7.2 Definitions

The following definitions may be used in discussions regarding the durability of a built-up wall/component.

7.2.1 Service life

Service life is the period over which the component or assembly delivers an acceptable performance. This is not necessarily the ‘as new’ performance.

7.2.2 Design life

The service life intended by the designer.

7.2.3 Demonstrable design life

Service life predicted from tests or previous experience.

7.2.4 Guaranteed life

Period of manufacturers’ responsibility. This is neither the service life nor design life.

7.3 Specification

The Specifier should agree the design life of the envelope system, with the Client or Building Owner, at an early stage in the building design process and before award of the contract for envelope system works.

The specification may include:

- specification of a design life for the façade;
- limitations on the materials that may be used;
- requirements to identify components that may require replacement and how they can be replaced.

The performance criteria of the wall should be satisfied for the full design life of the envelope system, as stated by the Specifier, provided always that the maintenance has been carried out as agreed with the Building Envelope Contractor.

7.4 Durability of components

The principle of primary and secondary components may be used to describe the various different elements/components which make up a built-up wall. It is clear that some components of the wall will not last for the full design life and will therefore need replacing, whereas others will last for 60 years plus.

In discussing primary and secondary components below, a 60-year design life has been assumed for the built-up wall.

It should be noted that a 60-year design life has been adopted in the UK for a normal life building (e.g. new health and educational buildings; new housing and high quality refurbishment of public buildings) as classified in the 1992 release of BS 7643 - *Guide to durability of buildings and building elements, products and components* which has subsequently been withdrawn. The Standard's replacement, the BS ISO 15686 series does not include a defined number of years for design life but provides a methodology for forecasting the service life of buildings and estimating the necessary maintenance and replacement of components.

7.4.1 Primary components

Primary components are all components with a forecast service life not less than the design life of the envelope system without the need for maintenance, other than regular cleaning.

7.4.2 Secondary components

Secondary components are all components with a forecast service life of less than the design life of the envelope system, assuming regular cleaning and maintenance in accordance with information to be provided by the manufacturer.

Secondary components must be replaceable (see Section 7.4.4).

7.4.3 Classifying components

Classifying the components of a built-up wall into primary and secondary components is not necessarily straightforward. The classification will depend on various factors and some components could be classified as either depending on the building in question. The matter should normally be resolved pre-contract on each project between competent persons acting for the relevant parties. *Table 7.1* shows a typical classification, with explanation given below where alternatives may exist.

Component	Primary	Secondary
Back wall	✓	
Internal linings	✓	✓
Thermal insulation (rainscreen)	✓	
Vapour control layer	✓	
Breather membrane	✓	
Rainscreen brackets	✓	
Cladding rails	✓	
Rainscreen panels	✓	✓
Thermal insulation (external render system)	✓	✓
Render	✓	✓
Window frame	✓	✓
Glazing		✓
Fixings	✓	
Fasteners	✓	✓
Interface seals	✓	✓

Table 7.1 - Primary and secondary components

7.4.3.1 Back wall

The back wall will always be a primary component, i.e. it is designed to last the lifetime of the wall.

The internal lining of the back wall will normally be a primary component. In domestic situations where not disturbing the inner surface of the wall is paramount it is most likely to be defined as a primary component, whereas in non-domestic buildings significant refurbishment is commonplace and disruption to the internal space is often acceptable. In such cases internal linings may be changed and therefore defined as a secondary component.

7.4.3.2 Rainscreen walls

The material, finish and external environment will determine whether rainscreen panels are primary or secondary components.

Panels made of a durable material such as stone or terracotta can be designed to last 60 years and may therefore be primary components. Metal panels of zinc, copper or stainless steel are very durable and will be classified as primary components. Anodised aluminium panels may also fall into this category but can depend upon exposure and frequency of cleaning. Where panels are primary components it should be noted that any panel fixings/fasteners also need a 60-year life.

Painted metal panels are likely to be secondary components and would be replaced for aesthetic reasons rather than due to material degradation as the paint finish ages and becomes unsightly. Alternatively, they may be painted on site to improve their appearance and increase their service life (see Section 7.8).

Other less durable materials such as timber will degrade and will require replacement at some time during the lifetime of the wall and will therefore be classified as secondary components.

Rails and brackets are likely to be primary components and can often be reused with new panels. One area of concern is where a proprietary system of rails and panels is used. If the original panels are no longer available and alternatives cannot be sourced, replacement of the rails may also be necessary, even if it were envisaged that they were primary components.

Other components of a rainscreen system, such as insulation and various membranes will generally be primary components. There may be scope for replacement of these components during refurbishment of the panels if it was discovered that this was required.

7.4.3.3 Externally insulated render systems

An EWIS may be designed to be either a primary or a secondary component. If the render is replaced during the lifetime of the wall, the insulation and fixings will also have to be replaced.

Some manufacturers have obtained third party certification for their systems which state that 'the systems should remain effective for at least 30 years, provided any damage to the surface finish is repaired immediately, and regular maintenance is undertaken'. This would suggest that render systems should be classified as secondary components requiring significant refurbishment/replacement during the lifetime of the building.

Research from the Fraunhofer Institute in Germany however predicts a 60-year life expectancy for externally insulated render systems. They have carried out long term, repeated inspections of buildings with such facades and have concluded that they suffer less damage than a conventional masonry wall with a render finish. This would allow the system to be classified as a primary component, however this is highly dependent on the detailing, workmanship and maintenance of the wall. It is thought that the buildings studied all feature masonry walls rather than lightweight timber or steel stud backing walls where movements will be greater.

As with the third party certificates they also say that any repairs to the render should be carried out immediately to avoid further damage to the wall.

7.4.3.4 Windows and glazing

Window frames will generally be secondary components, although they may be primary. The classification will depend on:

- frame material;
- finishes;
- environment;
- method of installation;
- building type.

Aluminium window frames may be classed as primary or secondary components. The frames themselves may last 60 years however their appearance will degrade with the extent depending upon the materials used, the environment and the frequency of cleaning; associated gaskets, sealants and glazed units will have shorter life expectancies.

An anodised finish will be the most durable in terms of appearance. Painted frames, such as polyester powder coating (PPC) are guaranteed for up to 30 years, but will be subject to fading etc. in that time.

Frames can be re-painted *in situ*, however the paint will not be as durable as the original finish and may require further re-painting during the remaining service life of the frame.

The decision whether to replace frames probably comes down to the type of building they are used in. In a single occupancy domestic building, owners are more likely to try and re-paint frames, or accept their reduced appearance, rather than replacing them. Maintenance and replacement in a block of apartments may be more complex. Apartment blocks are managed like commercial buildings, and any maintenance work requires collective decisions to be made by the numerous apartment owners, and reaching agreement is often difficult. Replacement is more likely in a non-domestic building.

PVC window frames will be secondary components, with a service life of typically 30 years, requiring little maintenance other than cleaning in that time.

Modern timber frames using quickly grown softwoods and protected with preservatives with low VOC content will not last as long as historical timber frames and are likely to be replaced at the same time as the glazing (see below). The service life of a timber frame may be extended with the addition of an aluminium external weathering profile. This will also require less maintenance.

For built-up walls with a typical 60-year design life, glazing units are secondary components. The replacement schedule for glazing will depend on factors such as:

- glazing unit type;
- frame type;
- environment.

The life expectancy of a glazing unit can vary significantly. A single-sealed unit in a non-drained-and-ventilated frame will give the shortest lifetime, which could be very short (e.g. o,ne or two years) up to typically around 15 years. A drained or drained-and-ventilated frame (*Figure 7.1*) will help prolong the life of the glazing unit and would be the preferred option. Drainage openings are provided that allow any water entering the glazing rebate to flow back to the outer face of the framing system, thus protecting the frame and edge of the glazing unit from prolonged exposure to water. A dual-sealed unit in such a frame should last longer, typically 25 years or more. In this situation building owners may try and extend this to 30 years so that a single replacement cycle is required.

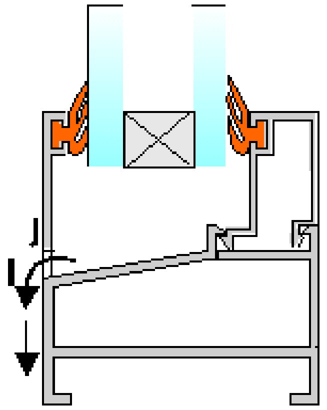


Figure 7.1 - Drained-and-ventilated aluminium frame

Replacement of glazing where there is a single building owner is straightforward. In blocks of apartments where there are multiple owners it may be more difficult. The first issue to address is whether glazing in the whole building is replaced in one go or whether a piecemeal approach to the work is taken. Such decisions will depend on factors including access requirements for the building work (whether the work can be carried out from inside or whether external access is required) and how the building is managed.

7.4.3.5 Fixings and fasteners

A fixing may be defined as a component providing the attachment of the structural frame or brackets to the primary structure or a back wall. Fixings will therefore generally be primary components.

A fastener may be defined as a component that attaches any two or more factory made components to one another, for example between a rainscreen panel and a rail. Therefore, a fastener may be defined as either a primary or secondary component depending on the materials used and the design life of the panels.

7.4.3.6 Interface seals

The classification of interface seals should consider the ease of replacing the seal. If the window is a primary component, the membrane seal between the window and the back may also be. Seals that are exposed, such as wet applied sealant between a window frame and external render, are more likely to be secondary components. A suitable maintenance strategy needs to be in place so such components can be replaced without impairing the integrity of the wall/interface.

7.4.4 Replacement of components

Secondary components should be capable of replacement without compromising the long-term structural or weatherproof integrity of the envelope system.

Architectural details permitting, in general, secondary components should be capable of replacement without progressive dismantling of the envelope system. A prime example of this is the replacement of rainscreen panels. For ad-hoc maintenance it should be possible to replace a single panel without disruption/dismantling of adjacent panels. This is especially important in vulnerable areas where damage is most likely, for example due to impact. Where panels cannot be replaced individually, measures should be taken to minimise the risk of damage, for example by using brickwork in vulnerable areas such as those that are heavily trafficked, see *Figure 7.2*. Where it is envisaged that single panel replacement will not be necessary, and only widespread replacement of panels will take place, this requirement may be relaxed.

Where the cost of replacing panels/components is very high, because for example roads require closing or specialist equipment is required, additional measures may be taken to minimise the risk of damage occurring, such as restricting public access to the wall etc.

Where more extensive replacement is required, for example in the event of a fire, it is important to consider whether the repairs are proportionate to the scale of the damage caused. Is the damage contained or is more widespread replacement necessary? For example, if the rainscreen panels have been bonded to support rails, how has the heat from the fire affected the integrity of the bond in the panels nearby but not directly subjected by the fire? Similarly, with bonded insulation in the case of insulated render system.

Figure 7.2 - Brickwork in vulnerable areas to reduce the risk of damage

Architectural details permitting, the requirement for components to be capable of replacement without progressive dismantling of the envelope system may be applied to primary components where there is a risk that they may be subject to accidental damage such as vehicle impact damage.

A key consideration in the replacement of window frames in a built-up wall is the ability to seal them into the backing wall. Various sealing methods may be used including membranes and wet-applied sealants. Successful re-sealing will depend on the materials and methods used, and the condition of the substrate to which the window is to be sealed in addition to any workmanship issues. It is difficult to guarantee the durability of replacement seals in these situations, and furthermore once they are covered they cannot be inspected or maintained.

The Building Envelope Contractor(s), Main Contractor, Specifier and Client shall agree the forecast design and service lives of all primary and secondary components and agree the required maintenance, replacement periods, and methods of replacement.

7.5 Suitability and compatibility of materials

The durability of a built-up wall may be compromised if unsuitable or incompatible materials are used in its construction.

7.5.1 Bimetallic corrosion

Bimetallic (or galvanic) corrosion is the accelerated corrosion of one metal placed in contact with a different metal, in the presence of an electrolyte which allows a flow of ions.

The risk of bimetallic corrosion depends on:

- the metals involved;
- their relative areas;
- electrolyte present.

In order for bimetallic corrosion to occur the metals in contact must have a large enough difference in potential between them. When placed in contact, the more anodic metal will corrode leaving the more cathodic metal protected. Metals can be listed in a galvanic series so that the risk may be assessed. A simplified galvanic series is shown in *Table 7.2*.

Zinc	**Increasingly active (anodic) – less noble**
Aluminium	
Stainless steel - active state[1)]	
Lead	
Copper alloys	
Stainless steel - passive state[2)]	**Increasingly passive (cathodic) - noble**

1) oxide film disrupted/steel exposed
2) oxide film intact

Table 7.2 - Simplified galvanic series

The speed at which a metal corrodes depends on the electro-potential difference between the two metals in contact - the greater the difference, the faster the rate of additional corrosion. The further apart the metals, the greater the potential difference and the more rapidly the anode (the less noble metal) will corrode.

The relative area of the metals in contact is an important consideration. The larger the cathode compared to the anode, the more oxygen reduction can occur and therefore the greater the corrosion.

For example, stainless steel is generally not a particularly potent cathode. However, it can cause problems where it is present in large areas in relation to small areas of active material, such as aluminium, in the presence of an electrolyte such as oxygen and moisture. Conversely, there is little or no risk of corrosion where the areas of aluminium are large in relation to the areas of stainless steel. See *Figure 7.3.*

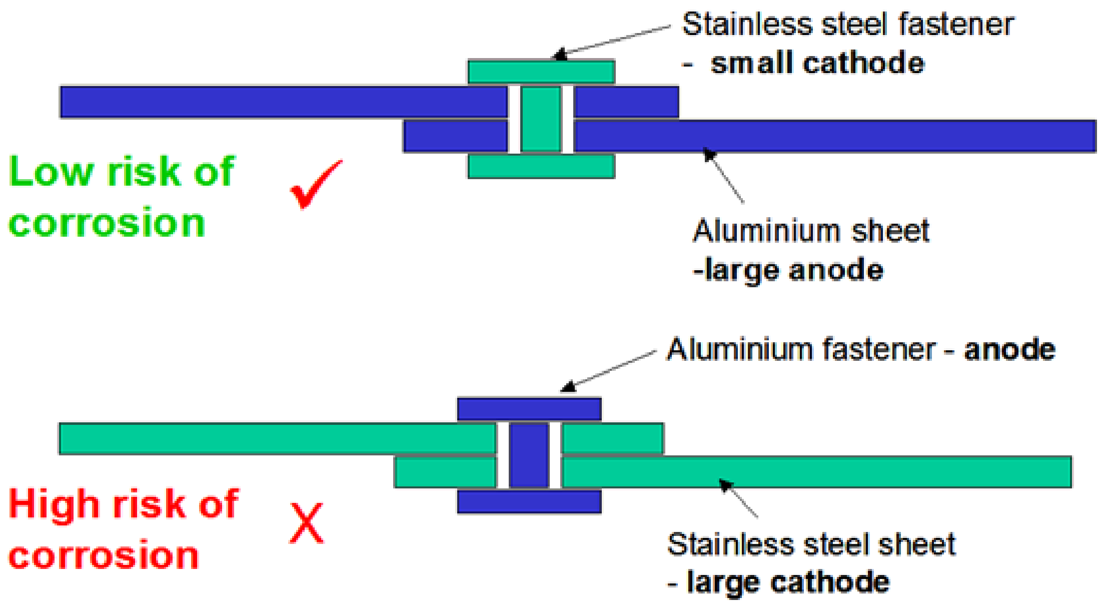


Figure 7.3 - Bimetallic corrosion examples

The risk is greater in polluted areas where the presence of aggressive ions such as chloride, acid or alkali increase the rate of corrosion.

The risk of bimetallic corrosion resulting from the contact between dissimilar metals shall be assessed and consideration given to the need to isolate materials.

Further guidance on the effects of different combinations of metals in various environments is given in PD 6484: *Commentary on corrosion at bimetallic contacts and its alleviation* published by British Standards Institution.

7.5.2 Water run-off

In addition to the bimetallic corrosion described above, general water management over the façade is important so that water run-off does not damage/stain adjacent materials. Examples include water running over some timbers or metals which subsequently stain nearby finishes, and water running over concrete staining glass below as shown in *Figure 7.4*.

Metals do not have to be in direct contact for bimetallic corrosion to occur. Particles of metal can be carried by rainwater over the surface of a second metal which can be enough to cause corrosion. This is principally a concern for run-off from copper, particularly on to less noble metals such as aluminium and zinc.

Water run-off from copper can also stain porous materials. This is also true of materials such as weathering steel which may be used for rainscreen panels.

Figure 7.4 - Run-off from concrete causing staining on glass below

Water run-off from timber can cause of number of issues. Firstly, acids may leach from the timber and if in sufficient quantities may cause corrosion of metals. This is more of an issue where water will collect, for example in guttering below timber cladding. This may also cause staining/discolouration of render materials.

The second issue associated with timber is that of leaching of copper based preservatives which can result in bimetallic corrosion of metals below.

7.5.3 Cementitious surfaces

All aluminium components in direct contact with damp cementitious surfaces, where there is a risk of corrosion, should be isolated. Suitable isolation materials include thin dense PVC, EPDM, zinc chromate coating, or bituminous paint.

7.5.4 Timber

Some timbers, particularly western red cedar, oak, sweet chestnut and Douglas fir, contain organic acids which can attack metals including copper, zinc, aluminium and lead.

Timber may have to be treated with preservative to achieve the required durability. The risk of corrosion of metal sheeting, brackets, fasteners and fixings in contact with timber should be assessed. The effect of any timber treatment shall be included in this assessment.

Timber preservatives containing copper salts can cause bimetallic corrosion of metal in contact with the timber. The resulting corrosion of fixings embedded in timber can cause breakdown of the timber and loss of holding power of the fixings (nail sickness). Formulations of preservatives are changing due to environmental and health concerns and manufacturers should be consulted for specific advice.

TRADA recommends the use of stainless steel fixings for timber in external cladding (TRADA: *Choose & Use – External wood cladding*).

7.5.5 Insulation materials

Due to the open joints in a rainscreen system there is a risk that the insulation within the cavity may be subject to wetting. The risk will depend on the:

- panel size;
- joint design;
- exposure (location, height of building).

It should be ensured that any wetting will not damage the insulation material or reduce its thermal performance. Where large amounts of water are predicted a non-absorbent insulation may be preferable.

7.6 Maintenance

A key aspect that will influence the durability of a built-up wall is the maintenance regime. Cleaning of facades may be required for the following reasons:

- to remove deposits that may cause deterioration. Dirt may contain aggressive substances including chlorides and acids which cause corrosion of metals and deterioration of finishes. They may also be hygroscopic thus retaining moisture and maintaining an aggressive environment for long periods;
- to maintain appearance;
- to preserve function, the commonest example being light transmission of glass;
- to maintain the validity of guarantees. Guarantees for some finishes require regular cleaning to be carried out.

Where access to the façade is required it is essential that designers ensure that maintenance can be carried out safely.

A logical approach to the design for safe maintenance needs to consider the following steps:

- maintenance strategy – this will include the frequency of maintenance, the activities to be carried out and hence the loads to be carried by the access equipment. All foreseeable maintenance activities should be included not just cleaning;
- selection of appropriate means of access – access needs to be appropriate for the tasks involved and compatible with the form of the building.

Further guidance on maintenance and access can be found in the following publications:

- CWCT - *Design of facades for safe access maintenance and repair*
- CIRIA C686 - *Safe access for maintenance and repair. Guidance for designers*
- BS 8560 - *Code of practice for the design of buildings incorporating safe working at height*

7.6.1 Maintenance strategy

The maintenance strategy determines the frequency with which access must be provided and the capacity of the access equipment. Frequent use will favour provision of permanent access equipment whereas occasional use will favour temporary equipment.

Operations to be considered are as follows:

- Cleaning;
- Inspection;
- isolated repair;
- widespread repair.

Other factors which affect maintenance are:

- selection of materials – maintenance requirements are related to material type and quality;
- size of components – determines the capacity of lifting equipment;
- detailing of the façade – to avoid dirt accumulation may increase intervals between cleaning (see Section 7.7);
- obstructions – such as brise soleil which may need to be removable to allow access for window replacement.

7.7 Designing to reduce cleaning and maintenance

Measures can be taken in order to minimise the cleaning requirements for the façade, such as:

- appropriate detailing;
- self-cleaning surfaces.

However, it is important that facades are cleaned at a frequency commensurate with the nature of the materials used and the local environment. For example, visible stainless steel in a marine environment will require more frequent cleaning than in a non-marine environment to avoid unsightly staining. Thus Clients and specifiers need to take care not to require unrealistically long intervals between cleaning.

If water can pool at any point, then algae can form and staining will occur. Additionally, water that evaporates will leave behind a residue. It is important that the façade is designed so that water can run off, particularly around ledges/shelves/window sills etc.

Controlling water run-off is important when thinking about façade cleaning and maintenance. Water running over the façade will help to wash away dirt, however care needs to be taken to ensure that the water does not simply deposit the dirt elsewhere. Flashings and sills should be used to throw water away from the façade so that this accumulation does not occur. This is particularly important when the water is running over materials such as timber and concrete, as the run-off may damage/stain adjacent materials.

Figure 7.5 shows an example where sill/flashing is incomplete and has resulted in dirt accumulation where water has run down the interface between the two wall types.

Figure 7.5 - Missing sill/flashing (left)

In conjunction with appropriate detailing of the façade, self-cleaning surfaces can further reduce the need for additional cleaning.

Self-cleaning glass has been commercially available since 2001, with the technology slowly expanding to other materials. Coatings are either hydrophilic (causing water to sheet on the surface) or hydrophobic (causing water to bead). Self-cleaning glass however, is only available up to certain sizes and with limitations on the processing that can be undertaken, thus is not always an option.

Self-cleaning renders are hydrophobic, *Figure 7.6*. The surface characteristics of the render are modified so that the contact area between dirt particles and water droplets is significantly reduced. Therefore, when a water droplet rolls across a surface it is able to pick up the dirt and remove it.

Figure 7.6- Self-cleaning render (hydrophobic)

Applying a durable self-cleaning coating to other materials has proven difficult but there are now products on the market, such as aluminium composite panels, which have a self-cleaning coating applied during the painting process. Such surfaces are hydrophilic. UV radiation helps to break down dirt on the surface which is then washed away by the flow of water.

All self-cleaning coatings rely on having sufficient water flowing over the surface. They will therefore not be as effective in areas which are protected from the rain by other parts of the building, or overhangs etc. Such areas would require more frequent cleaning.

7.8 Repairs to finishes

Finishes on metal panels may be damaged during or after construction and therefore may need to be repaired or replaced.

Repairs may be appropriate for small areas of damage, but it should be noted that site applied paints will have a different formulation and will therefore weather differently to factory applied finishes.

Where the extent of the damage is greater, there is usually no option but to remove the panels and replace or factory repaint them. Depending on the colour matching it may still be problematic due to different batches of paint being used.

Depending on their severity and position on the building, minor scratches may be polished out. This may be acceptable for solid colours but is not appropriate for metallic finishes.

In order to avoid/minimise damage during construction painted surfaces should be adequately protected with tapes/films etc.

Figure 7.7 shows a building where a number of the panels were damaged during construction and were subsequently repainted in situ.

The panels in question cover the flues of a building on a university campus. In this instance it was decided that panels which don’t match would be acceptable, however if the building was more prestigious/in a more prominent location this probably would not have been acceptable, and all the panels would have needed replacing.

Figure 7.7- Repaired metal panels

The method of repair for a render finish will primarily depend on the type of render used and the severity of the damage.

Simple cosmetic damage may be painted over. If this method is used it is vital that the correct paint type is used. EWIS are usually designed to be breathable; that is, they allow moisture vapour diffusing through the wall to escape rather than build up. The incorrect choice of paint may prevent the wall from breathing. Sealing the wall in that way would trap moisture within the wall which over time could cause serious material damage

Where a through-coloured render has been used (i.e. one with a colour pigment mixed in with the render), cosmetic damage can often be simply cleaned off. The advantage of a through-coloured render is that repainting is not required.

Where damage is more extensive, for example cracking, impact damage or moisture ingress, over-rendering may be necessary. The damaged area would need to be removed/cut out and new render applied and blended to existing wall. How successful this will be depends on the cause of the damage. If the damage had resulted from an impact this method of repair should be successful providing the integrity of the back wall has not been compromised. If the damage is cracking caused by movement then simply repairing the visible damage is unlikely to result in a long term solution if the movement is still occurring/movement provision is inadequate.

Depending on the colour and texture of the render, achieving a perfect match may be difficult. *Figure 7.8* shows a rendered wall which has been painted to cover graffiti. There is clearly an issue with colour match.

Figure 7.8 - Over painting graffiti on external render

8 SUMMARY CHECKLISTS

This chapter provides a summary to the guidance document in the form of checklists for built-up wall systems in both rainscreen and EWIS configurations. The checklists take a number of key aspects relating to the built-up wall and look at some of the items which should be considered or taken into account in its specification, design and construction. Many of the aspects and considerations will be common between the two configurations. Reference to relevant chapters and sections within the guidance document are provided for the various aspects and considerations.

8.1 Rainscreen built-up wall checklist

Table 8.1 is a summary checklist for built-up walls utilising a rainscreen outer finish.

Aspect	Consideration	Document Reference
Responsibility	Where does the responsibility for the built-up wall system lie during the various phases of the project? Where does the responsibility for the various interfaces lie? • Between the various layers • With abutments • With penetrations • With attachments	**Chapter 2** Section 2.3.5 Section 1.4 **Chapter 5**
Life expectancy	What is the expected service and/or design life for the built-up wall?	**Chapter 7**
	What components have been identified as secondary components requiring replacement during the service life/design life of the overall built-up wall?	Section 7.4 Section 7.4.3
Performance requirements	***Watertightness*** Is there an additional requirement for watertightness testing to achieve a particular specified performance?	**Section 6.1** Section 6.1.2 Section 6.1.3 Section 6.1.3.2
	What watertightness classification is required for any windows?	Section 6.1.2
	Airtightness What is the permissible air leakage for the building?	**Section 6.2** Section 6.2.2
	Do the built-up walls have an additional requirement to be airtightness tested?	Section 6.2.2
	What airtightness classification is required for any windows?	Section 6.2.2
	Structural Performance Is the back wall load bearing? How are the specified loads transferred back to the structural frame or back wall?	**Section 6.3** Section 6.3 Section 4.1.1 Section 6.3.3.1

	Have all probable loads acting on the built-up wall been taken into account and their magnitude determined? What is the deflection limits for the wall and its components?	Section 6.3.4 Section 6.3.5 Section 6.3.5.4
	Robustness What is the exposure category, safety classification and serviceability classification for the external surface of the built-up wall? What is the exposure grade for the internal surface of the built-up wall? Has a degree of redundancy been built into the design of the built-up wall to reduce the risk of progressive collapse should failure of a single or group of components occur?	**Section 6.4** Table 6.4.1, Table 6.4.2 and Table 6.4.3 Table 6.4.4 Section 6.4.8
	Movement Has the movement of the structure and back wall (e.g. floor slab deflection, inter storey drift, column shortening, settlement etc.) been determined and specified? Has movement due to temperature and moisture changes of the rainscreen system been taken into account in the design of support rails, brackets, fasteners joint and seals etc.? Has the movement of the structure, back wall and cladding been accommodated in the design of the interface details?	**Section 6.5** Section 6.5.1 Section 6.5.3 Section 6.5.2 Section 4.2.2 Section 5.3
	Fire Is there a requirement for the built-up wall to provide fire resistance and if so in what direction (inside to outside, outside to inside or both)? Have positions of compartment walls and floors been identified in order that fire stops can be designed and detailed? Is there a specific reaction to fire requirement for the exposed surface and potentially the cavity face of the rainscreen (e.g. where it less than 1 m from a boundary and/or more than 18 m above ground level)? Has the requirement for cavity barriers, their frequency and position been identified e.g. around window and door openings, 20 m maximum spacing etc?	**Section 6.6** Section 6.6.1.1 Section 4.2.4 Section 6.6.1.2 Section 6.6.1.3 Section 6.6.3.2.2 Section 4.2.4 Section 6.6.1.4 Section 6.6.3.2.3

	Is there a requirement for non-combustible (Class A2 or better) material within the rainscreen built-up wall (e.g. where it less than 1 m from a boundary and/or more than 18 m above ground level)? Does the overall fire strategy of the building have an alternative approach to meeting the requirements of the Building Regulations that may require the rainscreen built-up wall to be fire performance tested?	Section 6.6.1.5 Section 6.6.3.2.1 Section 6.6.1.6 Section 6.6.3.2 Section 6.6.2
	Thermal performance What are the target U-value requirements for the built-up wall, windows/glazing etc? Have U-value assessments been carried out taking into account all factors (e.g. thermal bridging) which can influence the thermal performance of the built-up wall? Have linear (Ψ-value) and point (χ-value) thermal performance assessments been carried out for interface and penetration details?	**Section 6.7** Section 6.7.1 Section 6.7.2 Section 6.7.3 Section 6.7.4 Section 6.7.5 Section 6.7.6 Section 6.7.9 Chapter 5 Section 6.7.6.2
	Condensation What are the internal and external psychrometric conditions? Have condensation risk analyses been carried out for both interstitial and surface condensation? Have condensation risk analyses been carried out for both interstitial and surface condensation at interface details?	**Section 6.8** Section 6.8.2.1 Section 6.8.3 Section 6.8.3
	Acoustics Is there a requirement for the built-up wall to provide a specific sound reduction performance? Is the sound reduction performance of the built-up wall to be specified as a single weighted value (R_w) or over specific full or one-third frequency bands? Is there a requirement for the interface of the built-up wall with internal partitions, floors and ceiling to be specifically detailed to limit flanking transmission?	**Section 6.9** Section 6.9.4 Section 6.9.5 Section 6.9.6 Section 6.9.2 Section 6.9.3.2
Other requirements	Other than meeting the requirements in national Building Regulations and standards are there any other organisation's requirements and standards (e.g. NHBC Technical Standards) that must be met?	Section 2.3.1
Back wall	What form of back wall is to be adopted (e.g. solid, framed, panels etc.)? Is the back wall to be continuous (e.g. in front of floor	Section 4.1.1 Section 4.1.1

	slabs) or as an infill between floor slabs?	
Functional design of wall	What type of rainscreen cavity is to be adopted: e.g. drained, drained and ventilated or pressure equalised? What is the minimum cavity width required?	Section 3.1.2 Section 3.2.4 Section 3.2.3 Table 3.1
Sheathing boards (for framed back walls)	Have the factors affecting the selection of a suitable sheathing board and thickness been determined e.g. internal and external psychrometric conditions, temporary exposure, cavity conditions, fixing requirements, stud spacing, movement allowance, load transfer, fire performance etc.? How are joints and penetrations in the sheathing board to be sealed?	Section 4.1.1.2.2 Section 4.1.1.2.2
Insulation	Have the factors affecting the selection of a suitable insulation type and thickness been determined e.g. thermal performance, acoustic performance, fire performance, thickness allowance etc.? Where is insulation to be positioned? How is the insulation to be fixed? Is there a requirement to tape joints between insulation boards?	Section 4.1.3 Section 0 Section 5.9 Section 6.8.3.5 Section 4.1.4 Section 4.1.3.6
Water barrier	How is watertightness of the built-up wall achieved and is there a requirement for a separate water barrier within it? Where is the water barrier to be positioned? How is the water barrier to be lapped within the built-up wall and at interfaces?	Section 5.3 Section 4.1.2 Section 5.8.1 Section 5.9 Section 5.3 Section 5.7 Section 5.10
Air barrier	How is airtightness of the built-up wall achieved and is there a requirement for a separate air barrier within it? Where is the air barrier to be positioned? How is the air barrier to be sealed to ensure continuity within the built-up wall and at interfaces?	Section 5.8.4 Section 5.9 Section 5.3 Section 5.6 Section 5.10
Vapour control	How is vapour control of the built-up wall achieved	Section 4.1.2

layer	and is there a requirement for a separate vapour control layer within it? Is the vapour control layer positioned on the warm side of the insulation behind the dew point position? How is the vapour control layer to be sealed to ensure continuity within the built-up wall and at interfaces?	Section 5.8.3 Section 6.8.3.6 Section 4.1.2.1 Section 5.9 Section 5.3 Section 5.6 Section 5.10
Breather membrane	Is there a requirement for a separate breather membrane within the built-up wall construction? Where is the breather membrane to be positioned? How is the water barrier to be lapped within the built-up wall and at interfaces?	Section 4.1.2 Section 5.3 Section 4.1.2.2 Section 5.9 Section 5.3 Section 5.6 Section 5.10
Rainscreen type and material	Will rainscreen type and material meet the project performance requirements as well as other factors such as: life expectancy, durability, external environment, appearance, size availability etc?	Section 3.2 Section 4.2.1 Chapter 7 Section 7.4.3.2
Rainscreen joints	What form of joint is to be adopted for the rainscreen? What is the minimum width requirement of the rainscreen joint?	Section 3.2.2 Section 3.2.2
Rainscreen support system, bracketry and fixings	Have the factors affecting the selection of the rainscreen support system, bracketry and fixings been determined e.g. compatibility with rainscreen panel type and material, ability to transfer loads, accommodation of movement and tolerance, fire performance, buildability etc. How and at what position are the support brackets fixed to the back wall to ensure safe transfer of loads?	Section 4.2.2 Section 4.2.3 Section 6.5.4.1 Section 4.2.2 Section 6.3.3.1
Material compatibility	Have any potential problems with compatibility between the various materials and components chosen for the rainscreen build-up wall system (e.g. bi-metallic corrosion) been identified and remedied? Have any potential problems of water run-off from one surface impacting on the durability and/or appearance of another been identified and remedied?	Section 7.5 Section 5.4 Section 7.5.2
Quality	Has a quality assurance procedure been put in place? Have hold points within the construction works been set?	Section 2.4 Section 2.4.2

	Have methods of quality checking been identified?	Section 2.4.3
Maintenance	Has a maintenance strategy been developed e.g. method and frequency of cleaning, method of repair to surfaces and finishes, future availability of materials, safe access for cleaning and maintenance (permanent or temporary equipment) etc? Can measures be taken in the design of the built-up wall and interfaces to assist in reducing the need/frequency of cleaning and maintenance? Can secondary components be replaced without compromising the long term structural and weatherproof integrity of the built-up wall?	Section 7.6 Section 7.8 Section 7.7 Section 7.4.4

Table 8.1 - Summary checklist for rainscreen built-up wall

8.2 EWIS built-up wall checklist

Table 8.2 is a summary checklist for built-up walls utilising a EWIS outer finish

Aspect	**Comment**	**Document Reference**
Responsibility	Where does the responsibility for the built-up wall system lie during the various phases of the project? Where does the responsibility for the various interfaces lie? • Between the various layers • With abutments • With penetrations • With attachments	**Chapter 2** Section 2.3.5 Section 1.4 **Chapter 5**
Life expectancy	What is the expected service and/or design life for the built-up wall? What components have been identified as secondary components requiring replacement during the service life/design life of the overall built-up wall?	**Chapter 7** Section 7.4 Section 7.4.3.3
Performance requirements	***Watertightness*** Is there an additional requirement for watertightness testing to achieve a particular specified performance? Is the EWIS independently certified? What watertightness classification is required for any windows?	**Section 6.1** Section 6.1.2 Section 6.1.3 Section 6.1.3.5 Section 6.1.2
	Airtightness What is the permissible air leakage for the building? Do the built-up walls have an additional requirement to be airtightness tested? What airtightness classification is required for any windows?	**Section 6.2** Section 6.2.2 Section 6.2.2 Section 6.2.2
	Structural Performance Is the back wall load bearing? How are the specified loads transferred back to the structural frame or back wall? Have all probable loads acting on the built-up wall been taken into account and their magnitude determined?	**Section 6.3** Section 3.3.2.2 Section 4.1.1 Section 6.3 Section 6.3.3.1 Section 6.3.4 Section 6.3.5

	What is the deflection limits for the wall and its components?	Section 6.3.5.4
	Robustness What is the exposure category, safety classification and serviceability classification for the external surface of the built-up wall? What is the exposure grade for the internal surface of the built-up wall? Has a degree of redundancy been built into the design of the built-up wall to reduce the risk of progressive collapse should failure of a single or group of components occur?	**Section 6.4** Table 6.4.1, Table 6.4.2, Table 6.4.3 Table 6.4.4 Section 161
	Movement Has the movement of the structure and back wall (e.g. floor slab deflection, inter storey drift, column shortening, settlement etc.) been determined and specified? Has the movement of the structure/back wall been accommodated in the design of the EWIS? Has the movement of the structure/back wall been accommodated in the design of the interface details?	**Section 6.5** Section 6.5.1 Section 6.5.3 Section 3.3.2 Section 5.2
	Fire Is there a requirement for the built-up wall to provide fire resistance and if so in what direction (inside to outside, outside to inside or both)? Have positions of compartment walls and floors been identified in order that fire stops can be designed and detailed? Is there a specific reaction to fire requirement for the exposed surface of the render finish (e.g. where it less than 1 m from a boundary and/or more than 18 m above ground level)? Has the requirement for cavity barriers, their frequency and position been identified e.g. around window and door openings, 20 m maximum spacing etc? Is there a requirement for non-combustible (Class A2 or better) material within the rainscreen built-up wall (e.g. where it less than 1 m from a boundary and/or more than 18 m above ground level)?	**Section 6.6** Section 6.6.1.1 Section 4.3.2 Section 6.6.1.2 Section 6.6.1.3 Section 6.6.3.3.2 Section 4.3.2 Section 6.6.1.4 Section 6.6.3.3.3 Section 6.6.1.5 Section 6.6.3.3.1

	Does the overall fire strategy of the building have an alternative approach to meeting the requirements of the Building Regulations that may require the use of an EWIS that has previously been fire performance tested or will need to be fire performance tested?	Section 6.6.1.6 Section 6.6.3.3 Section 6.6.2
	Thermal performance What are the target U-value requirements for the built-up wall, windows/glazing etc? Have U-value assessments been carried out taking into account all factors (e.g. thermal bridging) which can influence the thermal performance of the built-up wall? Have linear (Ψ-value) and point (χ-value) thermal performance assessments been carried out for interface and penetration details?	**Section 6.7** Section 6.7.1 Section 6.7.2 Section 6.7.3 Section 6.7.4 Section 6.7.5 Section 6.7.6 **Chapter 5** Section 6.7.6.2 Section 6.7.9
	Condensation What are the internal and external psychrometric conditions? Have condensation risk analyses been carried out for both interstitial and surface condensation? Have condensation risk analyses been carried out for both interstitial and surface condensation at interface details?	**Section 6.8** Section 6.8.2.1 Section 6.8.3 Section 6.8.3
	Acoustics Is there a requirement for the built-up wall to provide a specific sound reduction performance? Is the sound reduction performance of the built-up wall to be specified as a single weighted value (R_w) or over specific full or one-third frequency bands? Is there a requirement for the interface of the built-up wall with internal partitions, floors and ceiling to be specifically detailed to limit flanking transmission?	**Section 6.9** Section 6.9.4 Section 6.9.5 Section 6.9.6 Section 6.9.2 Section 6.9.3.2
Other requirements	Other than meeting the requirements in national Building Regulations and standards are there any other organisation's requirements and standards (e.g. NHBC Technical Standards) that must be met?	Section 2.3.1
Back wall	What form of back wall is to be adopted (e.g. solid, framed, panels etc.)?	Section 4.1.1

	Is the back wall to be continuous (e.g. in front of floor slabs) or as an infill between floor slabs?	Section 4.1.1
Functional design of wall	What is the approach to weathertightness to be adopted: face sealed or secondary defence with a cavity? **NB.** CWCT recommends that: only solid, load bearing, weathertight back walls up to 2 storeys high may be constructed without a secondary defence cavity. What is the position and size of the cavity?	Section 3.1 Section 3.3.2 Section 3.3.2
Sheathing/carrier boards	Have the factors affecting the selection of a suitable sheathing board and thickness been determined e.g. internal and external psychrometric conditions, temporary exposure, cavity conditions, fixing requirements, stud spacing, movement allowance, load transfer, fire performance etc? If EWIS is to applied to a carrier board have the factors affecting the boards suitability been determined e.g. compatibility with the render material, dimensional stability, impact resistance etc? How are joints and penetrations in the sheathing board to be sealed?	Section 4.1.1.2.2 Section 4.3.1.3 Section 4.1.1.2.2
Insulation	Have the factors affecting the selection of a suitable insulation type and thickness been determined e.g. thermal performance, acoustic performance, fire performance, thickness allowance etc.? Where is insulation to be positioned? How is the insulation to be fixed?	Section 4.1.3 Section 0 Section 5.9 Section 6.8.3.5 Section 4.1.4
Water barrier	How is watertightness of the built-up wall achieved and is there a requirement for a separate water barrier within it? Where is the water barrier to be positioned? How is the water barrier to be lapped within the built-up wall and at interfaces?	Section 5.3 Section 4.1.2 Section 5.8.2 Section 5.9 Section 5.3 Section 5.6 Section 5.10
Air barrier	How is airtightness of the built-up wall achieved	Section 5.8.4

	and is there a requirement for a separate air barrier within it? Where is the air barrier to be positioned? How is the air barrier to be sealed to ensure continuity within the built-up wall and at interfaces?	 Section 5.9 Section 5.3 Section 5.6 Section 5.10
Vapour control layer	How is vapour control of the built-up wall achieved and is there a requirement for a separate vapour control layer within it? Is the vapour control layer positioned on the warm side of the insulation behind the dew point position? How is the vapour control layer to be sealed to ensure continuity within the built-up wall and at interfaces?	Section 4.1.2 Section 5.8.3 Section 6.8.3.6 Section 4.1.2.1 Section 5.9 Section 5.3 Section 5.6 Section 5.10
Render	Will render type, thickness and finish meet the project performance requirements as well as other factors such as: life expectancy, durability, external environment, appearance, back wall, substrate quality etc? Is the render non-hydraulic and require a drying period to set, if so how is the surface to be protected over this period? If render is to painted, is the paint compatible with the render e.g. adherence, breathability etc.	Section 4.3.1 Section 4.3.1 Section 4.3.1.4
Reinforcement Mesh	Is there a requirement for a heavier grade of mesh to reinforce areas of potential high impact and mechanical loads? Has additional diagonal reinforcement mesh been incorporated at interface details such as windows and doors to minimise the risk of cracking of render?	Section 4.3.3 Section 4.3.3 Section 6.5.4.2
Trims	Have trims, beads etc. been incorporated at edges, junctions, joints etc.	Section 4.3.4
Material compatibility	Have any potential problems with compatibility between the various materials and components of the chosen build-up wall system been identified and remedied? Have any potential problems of water run-off from one surface impacting on the durability and/or appearance of another been identified and remedied?	Section 7.5 Section 5.4 Section 7.5.2

Quality	Has a quality assurance procedure been put in place? Have hold points within the construction works been set? Have methods of quality checking been identified?	Section 2.4 Section 2.4.2 Section 2.4.3
Maintenance	Has a maintenance strategy been developed e.g. method and frequency of cleaning, method of repair to surfaces and finishes, future availability of materials, safe access for cleaning and maintenance (permanent or temporary equipment) etc? Can measures be taken in the design of the built-up wall and interfaces to assist in reducing the need/frequency of cleaning and maintenance? Can secondary components be replaced without compromising the long term structural and weatherproof integrity of the built-up wall?	Section 7.6 Section 7.8 Section 7.7 Section 7.4.4

Table 8.2 - Summary checklist for EWIS built-up wall

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BUILT-UP WALLS TERMINOLOGY

Adhesive — A product used for bonding two components, for instance the insulation product to the wall substrate.

Air barrier — The particular layer of a wall that prevents excess air leakage through the wall. The air barrier should be continuous but may not lie in a single plane. It should be sealed to all penetrations, window frames, door frames and similar openings in the wall.

Air gap — The width of the clear space between the rainscreen and the back wall. This is measured between the back of the rainscreen panel and the outer face of the outermost component of the back wall, whether this be the insulation, a breather membrane or a continuous framing member.

Air permeability — Air permeability is used to describe the 'leakiness' of a structure or element. The higher the permeability the easier it is for air to pass through the structure.

Back wall — A back wall is either:

- A masonry or blockwork, loadbearing panel or infill panel, constructed to support a rainscreen overcladding system, or
- A dry lining system fixed to either the rainscreen support system or a separate inner frame or studs, or
- A cassette panel system similar to a stick curtain wall, or
- An existing masonry, blockwork or concrete wall used to support a refurbished rainscreen overcladding system.

The back wall will either form, or support, the air barrier of the wall. When refurbishing building envelopes it may be necessary to modify the back wall to achieve the air leakage rates required. The back wall also carries the wind loading.

Baffle — Component that is either inserted into a joint or placed immediately behind a joint to prevent the direct passage of water through the joint

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

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

Base coat: — In a render system, the coat applied directly onto the insulation product; the reinforcement is embedded into it and provides most of the mechanical properties of the rendering,

Breather membrane — A layer within the construction that allows the passage of air and water vapour but is resistant to the passage of liquid water. This is sometimes used within a rainscreen wall to prevent water from reaching the insulation or other parts of the back wall whilst allowing the wall to breathe.

Brick slip — Brick slips are a lightweight, thin facing applied to a built-up wall to give the impression of traditional brick wall finish. The brick slips themselves may be thin clay bricks or a synthetic alternative

Building envelope contractor — The company responsible under the contract for the detailed design, manufacture, supply and installation of a contract package of the building envelope.
Each of these tasks may be subcontracted to specialists, but there shall be a single controlling authority with overall responsibility for the cladding package.

Built-up wall — Essentially layered construction
Multiple suppliers and layers of components
Constructed at site

Capillary Action	(capillarity, capillary motion, or wicking) is the ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to, external forces like gravity.
Cavity	The space between the back of the rainscreen and the air barrier. This normally contains the insulation, support framework and fixings
Cavity closer	A barrier that acts to compartment the cavity as required for reasons of pressure-equalisation or firestopping
Cavity ventilation	The passage of air into the cavity in order to dry residual water and encourage evaporation of moisture.
Cladding fixing	Device to support or tie back cladding units to the structure
Cladding package	A zone of the building envelope that is the responsibility of a single building envelope contractor.
Cladding restraint fixing	Device to restrain or tie back cladding units to the structure (a fixing that transfers only wind load)
Cladding support fixing	Device that carries the dead load of the cladding units
Compartment	The volume of cavity bounded by horizontal and vertical cavity closers.
Compartmentation	The provision of cavity closers to form discrete compartments within the cavity. This restricts the movement of air in order to achieve pressure-equalisation. It may also resist the movement of smoke within the cavity.
Condensation	Process whereby water is deposited from air containing water vapour when its temperature drops to dew-point, or the vapour pressure rises above the saturated vapour pressure at a given temperature Condensation may form on the inner or outer surface of the wall (surface condensation), or within the wall element (interstitial condensation).
Decorative coat:	In a render system, the coat which generally contributes to the aesthetic finishing (to cover efflorescence ...) of finishing coat and can also provide supplementary protection against weathering.
Design life	The intended service life
Drained principle	Drained systems are secondary defence systems that allow water to drain from between the inner and outer seals through suitably protected openings in the outer seal.
Dry butt joint	Joint in which units abut each other without any jointing material
Dry zone	Part of a rainscreen system that can always be assumed to be protected from rainfall, generally on the inside of the watertight layer
Durability	The ability of a material or component to provide acceptable performance for a period of time
EIFS	Exterior Insulated Finish System, **See EWIS**
Element	A zone of the building envelope constructed in a common style from the same envelope system. This should not be confused with the term cladding package which relates to a zone of cladding covered by a single contract.
ETICS	Exterior Thermal Insulation Composite System, **See EWIS**
EWIS	Exterior Wall Insulation System; This terminology is used by the British Board of Agrement (BBA) and is widely

	understood in the UK
Expansion joint	A joint designed to allow components to expand without damaging adjoining components
Face-sealed principle	Envelopes of this type reply on a single seal or watertight layer at or near the outer surface to prevent water ingress and provide airtightness.
Fastener	Screw, bolt, rivet or similar component used to secure two or more components together, typically as part of a framing or bracket system
Fixing bracket	Discrete component used as an intermediate connector to join two other components together *NOTE A fixing bracket typically allows for construction tolerances and different orientations of the components to be joined.*
Filled joint	Joint that makes use of a jointing product to fill the gap between adjacent parts
Finishing coat:	In a render system, the coat which contributes to the protection against weathering and can provide a decorative finish; it is applied onto the base coat with or without a key coat,
Fire barrier	An element of construction, such as a wall, partition or glazed screen, which give an appropriate level of fire resistance.
Fire performance	The length of time an element of construction, such as a wall, partition or glazed screen, continues to give fire resistance when tested under simulated fire conditions according to BS 476: Part 20.
Fire resistance	The ability of an element of construction, such as a wall, partition or glazed screen, to maintain integrity and/or insulation when tested under simulated fire conditions according to BS 476: Part 20.
Fire stop	Barrier that is placed in a cavity to prevent the passage of flame from one part of the cavity to another *NOTE Fire stops are also known as fire cavity barriers.*
Fixing	A component providing the attachment of the rainscreen framework to the primary structure or the background wall. This includes components providing attachment of a backing wall to the primary structure.
Flashing	Sheet metal or other material applied to seal and protect the joints formed by different materials or surfaces
Gasket	Pre-formed rubber component that is used to seal a joint
Insulation product	A pre-fabricated product, with a high thermal resistance, which is intended to impart insulating properties to the substrate to which it is applied.
Integral rainscreen wall	A panellised backing wall, which is supported within the supporting framework of a rainscreen.
Interface	Interfaces occur where two different systems meet or where some other element of the building meets with the building envelope. Interfaces are a common source of air and water leakage and are often bespoke to a project
Joint	A joint is formed by the close proximity of the surfaces of two adjacent components. A joint generally passes from one exposed surface of the building facade to the other, although it might be defined as passing from one exposed surface to some significant cavity within the facade.
Key coat:	Within a render system, a very thin coat which may be applied to the base coat and is intended to act as a preparation for the application of the finishing coat. It can also be

	eventually used for aesthetic reason (for example in case of “dark” ribbed finishing coats),
Labyrinth joint	Open joint between two panels, or between a panel and an adjacent element of construction, that contains a complex baffle designed to cause several changes of air flow direction *NOTE The construction of the joint prevents the direct passage of water through the joint and also provides changes of direction in order to shed water droplets from the air flow through the joint.*
Lath	Wire mesh that is applied to a substrate as a matrix over which a render is applied.
Lining	Internal boards, typically plasterboard, attached to a framed backing wall or drylining system.
Main contractor	The company responsible for procurement, management and coordination of the entire building works.
Mechanical fixing devices	Profiles, anchors, pins or any special fixing devices used to secure to the substrate
Movement joint	A joint designed specifically to accommodate partial opening resulting from movement of the structure relative to the cladding
Open joint	Joint between two panels, or between a panel and an adjacent element of construction, not closed by any sealing element, thereby permitting the free passage of air through the joint
Overcladding	Where a new or existing wall of concrete, brickwork or blockwork forms the inner leaf of the wall the rainscreen cladding is called overcladding.
Performance specification	A set of requirements for the finished wall. Performance specification places the onus for detailed design with the specialist contractor.
Prescriptive specification	A set of simple requirements that leave no room for interpretation.
Pressure-equalisation	The principle of allowing air to enter the cavity between the rainscreen and the air barrier and then restricting its movement to generate a balancing pressure within the cavity. This reduces differential wind pressure across the rainscreen and so reduces air and water movement through the joints of the rainscreen
Quality assurance (QA)	A system of demonstrating the attainment of quality standards in a project.
Rainscreen	The particular layer of a wall, normally the outermost, that prevents the gross passage of rain through or into the wall. the rainscreen may not all lie in one plane, and may not be continuous. It may contain open joints and flashings to windows and other penetrations. For any rainscreen cladding system it should be possible to identify a rainscreen that sheds water from the building.
Rainscreen cladding	A system of components assembled on the face of a building to form a multi-layered wall that provides a barrier to wind and rain, by means of a rainscreen
Reinforcement	Glass fibre mesh, metal lath or plastic mesh reinforcement (embedded) as well as fibres (dispersed) in the base coat to improve its mechanical strength.
Rendering system	All the coats applied to the outer face of the insulation product together with the reinforcement
Sealant	Unformed flexible material applied in joints to prevent the passage of moisture, wind and dust

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

Sealant tape — Impregnated foam sealing tapes used in place of a wet-applied sealant.

Secondary defence principle — Envelopes of this type have seals at or near both the inner and outer faces. The outer seal should be the primary barrier to water ingress. The inner seal provides airtightness and acts as a secondary seal to water ingress.

Service life — Period of time after installation during which a facility or its component parts meet or exceed the performance requirements

Sheathing board — Board attached to the outer surface of the studs in a framed backing wall. Sheathing boards provide a flat and stable surface onto which insulation/membranes for vapour control can be fixed. They will also contribute to the racking strength of the wall

Slightly ventilated air cavity — A slightly ventilated air layer is one in which there is provision for limited air flow through it from the external environment by openings of area, *A*v, within the following ranges:

- >500 mm2 but <1500 mm2 per metre of length (in the horizontal direction) for vertical air layers;
- >500 mm2 but <1500 mm2 per square metre of surface area for horizontal air layers.

Smoke stop — Barrier that is placed in a cavity to prevent the passage of smoke from one part of the cavity to another

Specialist contractor — Contractor utilising specialist skills and knowledge and making a design input to the contract. May be employed as a sub-contractor or directly by the client.

Substrate — A wall, which in itself already meets the necessary airtightness and mechanical strength requirements (resistance to static and dynamic loads).

Surface Tension — Results from the greater mutual attraction of liquid molecules than any attraction to the air molecules at liquid-to-air interfaces. The cohesion between water molecules is stronger than the low adhesion of water to air molecules. There is a resultant force at the surface that causes the liquid to behave as if it were covered in a tense membrane.

Thermal insulation material — Material that is intended to reduce heat transfer and that derives its insulation properties from its chemical nature and/or its physical structure

Thermal transmittance — An alternative term for U-value

Thermal bridge — Part of the building envelope where the otherwise uniform thermal resistance is significantly changed by:

- Full/partial penetration of the building envelope by materials with a different thermal conductivity, and/or
- A change in thickness of the fabric, and/or
- A difference between internal and external areas, such as occur at wall/floor/ceiling junctions

Unventilated air cavity — An unventilated air layer is one in which there is no express provision for air flow through it.

U-value — A measure of the rate of heat loss through the wall or a component in a wall of a building, also described as thermal transmittance. U-values depend on several different variable factors, such as wind speed and temperature, so they are usually quoted in relation to a specific set of steady state environmental conditions.

Vapour control layer — A layer within the construction that retards the passage of water vapour through the wall.

Note that an air barrier may function as a vapour control layer, and the positioning of the air barrier must therefore be considered with this in mind.

Vented air space	Cavity or void that has openings to the outside air placed so as to allow some limited, but not necessarily through, movement of air
Ventilated air space	Cavity or void that has openings to the outside air placed so as to promote through movement of air
Well-ventilated air cavity	A well-ventilated air layer is one for which the openings between the air layer and the external environment are equal to or exceed • 1500 mm2 per metre of length (in the horizontal direction) for vertical air layers, • 1500 mm2 per square of metre of surface area for horizontal air layers.
Wet zone	Part of the rainscreen system that can be assumed to be exposed to rainwater, either directly or as a result of water flowing through joints and gaps in the system *NOTE It is usually possible to identify one layer of the construction as being the watertight layer. All parts of the construction outside this layer should be assumed to be in the wet zone.*
Work package	Contract to supply a particular part of the building envelope/layer in a built-up wall.

A. INTERFACE EXAMPLES

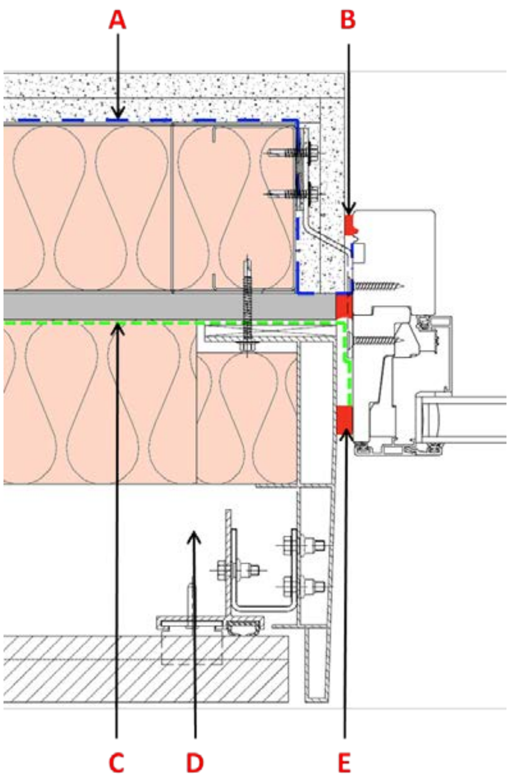
Although interfaces in general have been covered in Chapter 5 this chapter provides a selection of examples which looks at the detailing at some typical interfaces. The examples include both rainscreen and EWIS forms of construction and include a commentary on the purpose and function of the various layers and seals utilised within the detail.

It is the intention that further details will be added to this chapter overtime, and we ask for further example interfaces which may be added to this section.

A.1 Rainscreen interface details

A.1.1 Window jamb interface with rainscreen, framed back wall (insulated)

This detail (*Figure A.1.1*) shows a typical interface of a rainscreen built-up wall system with a window jamb. The built-up wall system has a framed back wall which is insulated.



A	Internal membrane (if required)
B	Internal sealant joint/tape
C	Membrane (if required)
D	Drained and ventilated cavity
E	External sealant joint/tape

Figure A.1.1 – Window jamb interface with rainscreen, framed back wall (insulated)

A The internal membrane should be **vapour resistant**, which if installed correctly, will function as a **vapour control layer** and the **air barrier**.

Foil-backed plasterboard may be used to reduce the vapour transfer through the wall. Joints between boards will reduce the vapour resistance, and their effect should be included

B A suitable seal is required between the lining and the back of the curtain wall frame to ensure continuity of the **air/vapour barrier**. This joint has to be compatible with the adjacent materials and be designed to accommodate the differential movement which will occur between the back wall and the curtain wall. This may consist of a tape or wet-applied sealant, with or without a membrane seal between the two systems.

C **Water resistant membrane.** If the **dew point** is within the **back wall**, a **breather membrane** should be used in this location. This will act as the **water barrier** and if appropriately selected, may also function as the **air barrier**.

If the **dew point** is within the **rainscreen insulation**, a **vapour resistant membrane** can be used, which will function as the **vapour control layer, water and air barrier**.

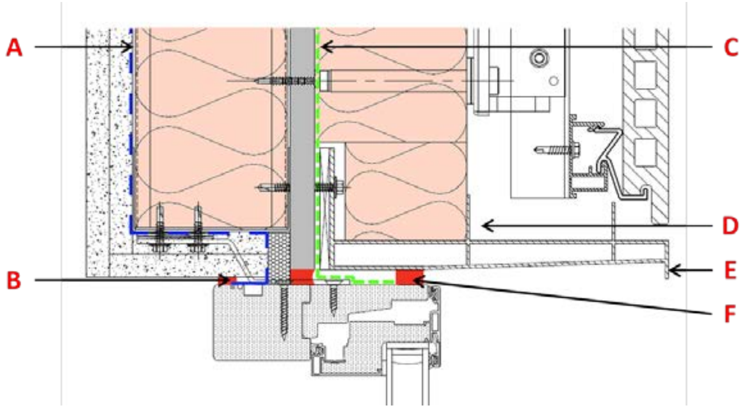
As a minimum requirement the sheathing boards should be water resistant and the joints between the boards robustly sealed. This will then act as the air and water barrier, however will not be as robust as including an appropriate membrane on the outer face of the sheathing. Consideration must be given to the position of the **vapour control layer**.

D Rainscreen cavity

E **Primary water seal**

A.1.2 Window pod head interface with rainscreen, framed back wall (insulated)

This detail (*Figure A.1.2*) shows a typical interface of a rainscreen built-up wall system with a window head. The built-up wall system has a framed back wall which is insulated.



A Internal membrane (if required)

B Internal sealant joint/tape

C Waterproof membrane (if required)

Cavity drainage

D Water management

E External sealant joint/tape

F

Figure A.1.2 – Window pod head interface with rainscreen, framed back wall (insulated)

A The internal membrane should be **vapour resistant**, which if installed correctly, will function as a **vapour control layer** and the **air barrier**.

Foil-backed plasterboard may be used to reduce the vapour transfer through the wall. Joints between boards will reduce the vapour resistance, and their effect should be included.

B **Internal seal** to maintain **continuity of air barrier/VCL**. Seal must be able to accommodate any differential movement between the back wall and the window frame. May be a tape or wet applied sealant.

C **Water resistant membrane.** If the **dew point** is within the **back wall**, a **breather membrane** should be used in this location. This will act as the **water barrier** and if appropriately selected, may also function as the **air barrier**.

If the **dew point** is within the **rainscreen insulation**, a **vapour resistant membrane** can be used, which will function as the **vapour control layer, water and air barrier**.

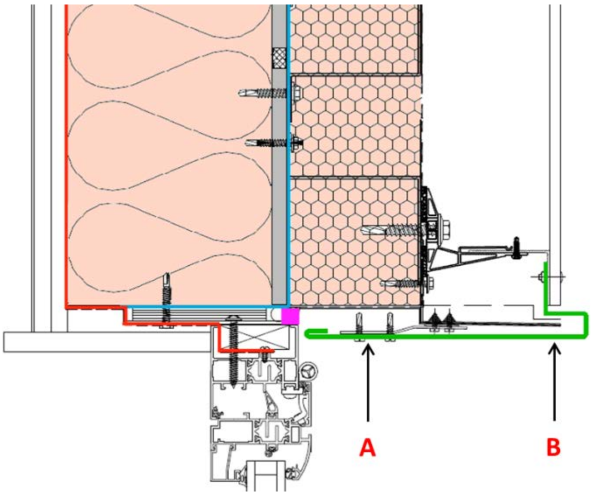
D Provision must be made for water running down the rainscreen cavity. Water should be able to **freely drain** out of the cavity at the window head. Holes may need to be provided in components such as window pods/revel liners to allow any water to drain.

E Water running down the face of the rainscreen should not be able to track back along window pods/revel liners, to vulnerable areas of the wall. **Drip details/breaks/upstands** may need to be incorporated.

F **Primary water seal**. **Weep holes** may need to be provided to allow any water that has reached the back wall to drain out of the interface.

A.1.3 . Window head interface with rainscreen, framed back wall (insulated)

This detail (*Figure A.1.3*) shows a typical interface of a rainscreen built-up wall system with a window head. The built-up wall system has a framed back wall which is insulated. The detail is included as an alternative to *Figure A.1.2*, and has a reveal pressing in place of the window pod.



A Reveal pressing/detail

B Drainage

Figure A.1.3 – Window head interface with rainscreen, framed back wall (insulated)

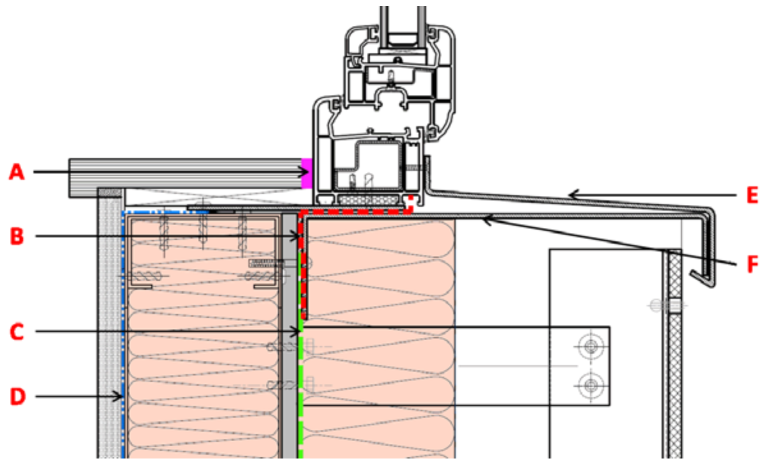
This detail is included as an alternative to *Figure A.1.2*, showing a reveal pressing in place of the window pod. Other details and components are as *Figure A.1.2.*

A **Reveal pressing**. Stops short of the window so that any water tracking back along the pressing does not come into contact with the seal between the window head and built-up wall.

B **Drainage openings** required to allow water in the rainscreen cavity to be removed.

A.1.4 Window sill interface with rainscreen, framed back wall (insulated)

This detail (*Figure A.1.4*) shows a typical interface of a rainscreen built-up wall system with a window sill. The built-up wall system has a framed back wall which is insulated.



A Internal sealant joint/tape

Membrane flashing

B

Waterproof membrane

C Internal membrane (if required)

D Sill detail

Sill support

E

F

Figure A.1.4 – Window sill interface with rainscreen, framed back wall (insulated)

A **Internal seal** to maintain **continuity of air barrier/VCL**.

B This membrane should be lapped over any other membrane fixed to the sheathing (C) so that any water present will be kept out of the back wall. If this membrane is to form part of the air barrier, then membrane C should be selected to function as an **air barrier**.

C **Water resistant membrane.** If the **dew point** is within the **back wall**, a **breather membrane** should be used in this location. This will act as the **water barrier** and if appropriately selected, may also function as the **air barrier**.

If the **dew point** is within the **rainscreen insulation**, a **vapour resistant membrane** can be used, which will function as the **vapour control layer, water and air barrier**.

D The internal membrane should be **vapour resistant**, which installed correctly, will function as a **vapour control layer** and the **air barrier**.

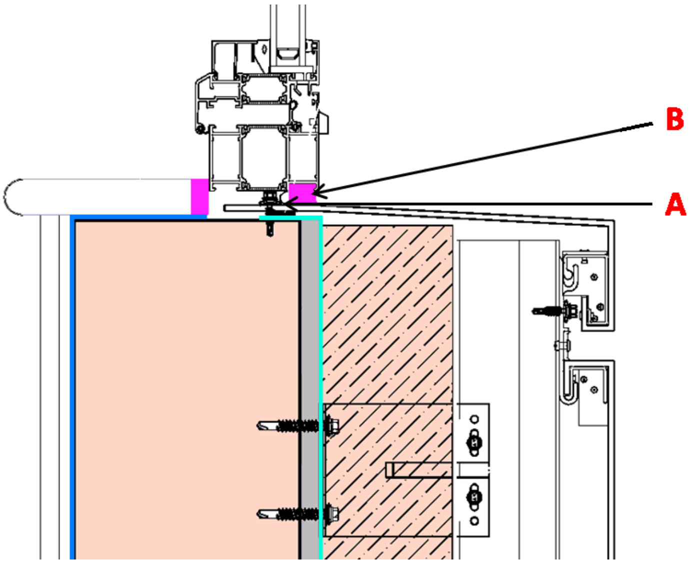
Foil-backed plasterboard may be used to reduce the vapour transfer through the wall. Joints between boards will reduce the vapour resistance, and their effect should be included

E **Sill detail**. Should be robustly fixed to the window.

F **Sill Support.** Thermal bridging should be avoided.

A.1.5 Window sill interface with rainscreen, framed back wall (insulated)

This detail (*Figure A.1.5*) shows a typical interface of a rainscreen built-up wall system with a window sill. The built-up wall system has a framed back wall which is insulated. The detail is included as an alternative to *Figure A.1.4*. and has a different sill detail.



A Sill detail

B External sealant joint/tape

Figure A.1.5 – Window sill interface with rainscreen (alternative), framed back wall (insulated)

This detail is included as an alternative to *Figure A.1.4*, showing a different sill detail. Other details and components are as *Figure A.1.4*.

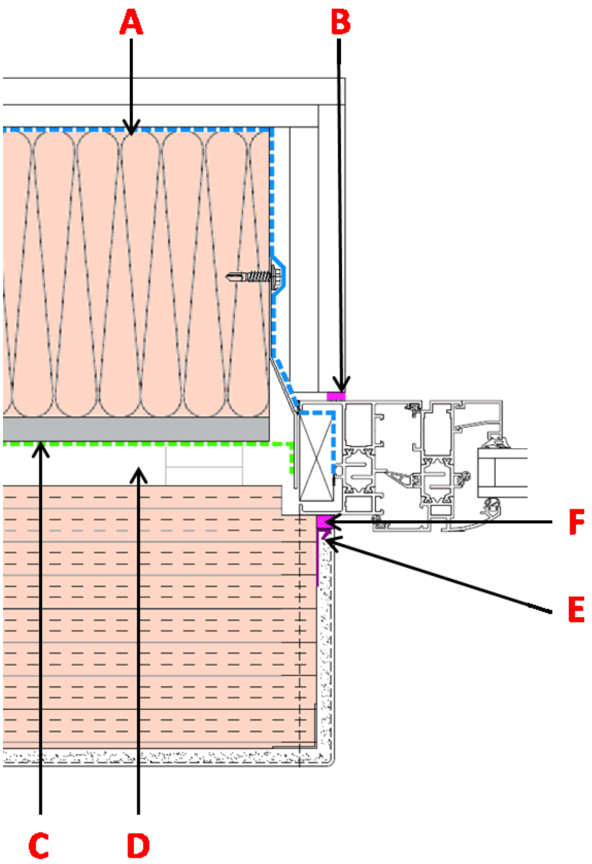
A **Sill detail**. Here the sill profile extends beyond the front face of the window frame and is fixed to the back wall. A sealant joint is required between the window frame and the sill profile.

B **Primary water seal** as described above. The performance of this joint is highly dependent on workmanship and as such is a possible area of weakness.

A.2 EWIS interface details

A.2.1 Window jamb interface with EWIS, framed back wall (insulated)

This detail (*Figure A.2.1*) shows a typical interface of an EWIS built-up wall with a window jamb. The built-up wall system has a framed back wall which is insulated and includes a drained cavity.



A Internal membrane (if required)

B Internal sealant joint/tape

C Membrane (if required)

D Drained cavity

E Edge profile

F External sealant joint/tape

Figure A.2.1 – Window jamb interface with EWIS, framed back wall (insulated)

A If the **dew point** is within the back wall the **internal membrane** should be **vapour resistant**, which if installed correctly, will function as a **vapour control layer** and the **air barrier**.

A **membrane flashing** may be installed between the window frame and the internal lining/back wall. If the flashing is to be joined to another membrane, a suitable adhesive must be used, and a sufficient overlap provided.

A **plastered surface** may form the **air barrier** and will **limit vapour transfer.**

Foil-backed plasterboard will **limit vapour transfer** through the wall. Its performance will largely depend on how well **gaps between adjacent boards are sealed**. Any gap will severely limit the performance.

B A suitable seal is required between the lining and the back of the window frame to ensure continuity of the **air/vapour barrier**. This joint has to be compatible with the adjacent materials and be designed to accommodate the differential movement which will occur between the back wall and the window.

C If the **dew point** is within the **back wall** this membrane should be **vapour permeable**. A **breather membrane** in this position would act as the **water barrier**, and if appropriately specified, the **air barrier**.

If the **dew point** is in the **external insulation**, a **VCL** can be used.

As a minimum requirement the sheathing boards should be water resistant and the joints between the boards robustly sealed. This will then act as the air and water barrier, however will not be as robust as including an appropriate membrane on the outer face of the sheathing.

If relying on the sheathing boards a **membrane flashing** between the **window frame** and the **sheathing boards** is recommended to protect the back wall at the interface.

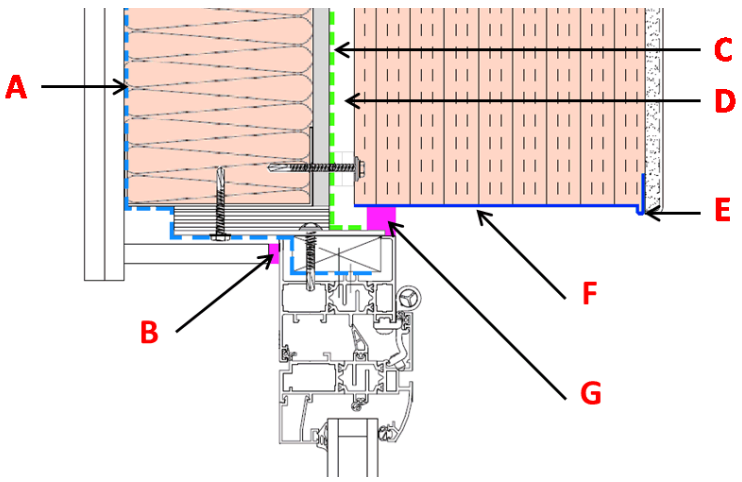
D A **drained cavity** is recommended when EWIS is used on a **metal framed back wall**.

E **Render profile/bead**. This provides a defined edge to seal between the render and the window frame (F).

F **Primary water seal.**

A.2.2 Window head interface with EWIS, framed back wall (insulated)

This detail (*Figure A.2.2*) shows a typical interface of an EWIS built-up wall with a window head. The built-up wall system has a framed back wall which is insulated and includes a drained cavity.



A	Internal membrane (if required)
B	Internal sealant joint/tape
C	Membrane (if required)
D	Drained cavity
E	Drip detail
F	Render starter track
G	External sealant joint/tape

Figure A.2.2 – Window head interface with EWIS, framed back wall (insulated)

A If the **dew point** is within the back wall the **internal membrane** should be **vapour resistant**, which if installed correctly, will function as a **vapour control layer** and the **air barrier**.

A **membrane flashing** may be installed between the window frame and the internal lining/back wall. If the flashing is to be joined to another membrane, a suitable adhesive must be used, and a sufficient overlap provided.

A **plastered surface** may form the **air barrier** and will **limit vapour transfer.**

Foil-backed plasterboard will **limit vapour transfer** through the wall. Its performance will largely depend on how well **gaps between adjacent boards are sealed**. Any gap will severely limit the performance.

B A suitable seal is required between the lining and the back of the window frame to ensure continuity of the **air/vapour barrier**. This joint has to be compatible with the adjacent materials and be designed to accommodate the differential movement which will occur between the back wall and the window.

C If the **dew point** is within the **back wall** this membrane should be **vapour permeable**. A **breather membrane** in this position would act as the **water barrier**, and if appropriately specified, the **air barrier**.

If the **dew point** is in the **external insulation**, a **VCL** can be used.

As a minimum requirement the sheathing boards should be water resistant and the joints between the boards robustly sealed. This will then act as the air and water barrier, however will not be as robust as including an appropriate membrane on the outer face of the sheathing.

If relying on the sheathing boards a **membrane flashing** between the **window frame** and the **sheathing boards** is recommended to protect the back wall at the interface.

D A **drained cavity** is recommended when EWIS is used on a **metal framed back wall**.

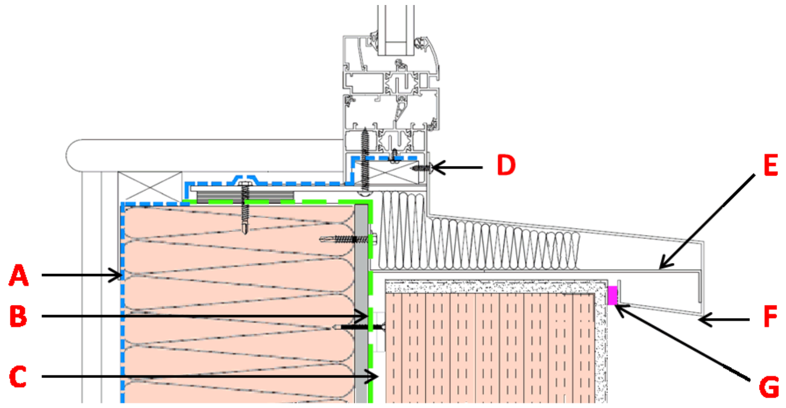
E A suitable **drip detail** is required to ensure water running down the face of the wall is directed away from the junction with the window.

F **Render starter track**. This may require **drainage openings** to drain any water passing the external render.

G **Primary water seal.** Provision should be made for **drainage** of any water in the cavity through weep holes etc.

A.2.3 Window sill interface with EWIS, framed back wall (insulated)

This detail (*Figure A.2.3*) shows a typical interface of an EWIS built-up wall with a window sill. The built-up wall system has a framed back wall which is insulated and includes a drained cavity.



A Internal membrane (if required)

B Cavity membrane (if required)

Drained cavity

C Sill profile

D Drainage

E Water management / drip detail

F

External sealant/tape

G

Figure A.2.3 – Window sill interface with EWIS, framed back wall (insulated)

A If the **dew point** is within the back wall the **internal membrane** should be **vapour resistant**, which if installed correctly, will function as a **vapour control layer** and the **air barrier**.

A **membrane flashing** may be installed between the window frame and the internal lining/back wall. If the flashing is to be joined to another membrane, a suitable adhesive must be used, and a sufficient overlap provided.

A **plastered surface** may form the **air barrier** and will **limit vapour transfer.**

Foil-backed plasterboard will **limit vapour transfer** through the wall. Its performance will largely depend on how well **gaps between adjacent boards are sealed**. Any gap will severely limit the performance.

B If the **dew point** is within the **back wall** this membrane should be **vapour permeable**. A **breather membrane** in this position would act as the **water barrier**, and if appropriately specified, the **air barrier**.

If the **dew point** is in the **external insulation**, a **VCL** can be used.

As a minimum requirement the sheathing boards should be water resistant and the joints between the boards robustly sealed. This will then act as the air and water barrier, however will not be as robust as including an appropriate membrane on the outer face of the sheathing.

If relying on the sheathing boards a **membrane flashing** between the **window frame** and the **sheathing boards** is recommended to protect the back wall at the interface.

C A **drained cavity** is recommended when EWIS is used on a **metal framed back wall**.

D Sill Profile

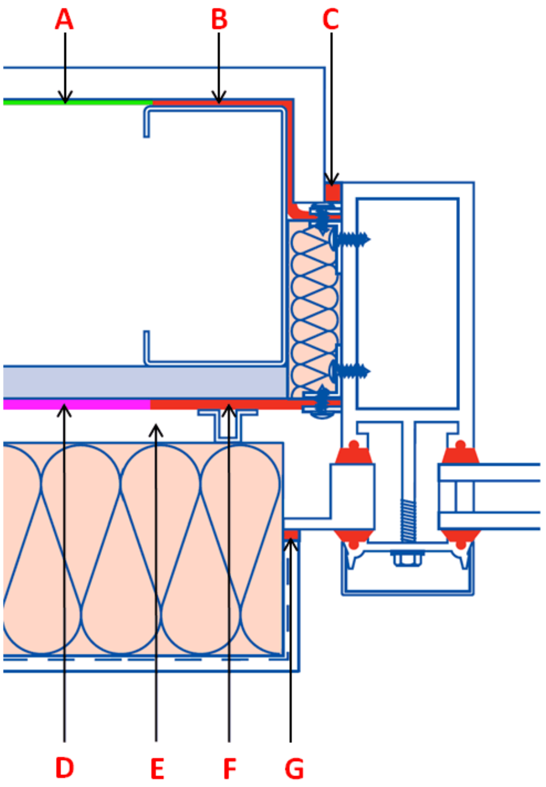
E **Drainage openings** required to allow water in the cavity to be removed.

F A suitable **drip detail** is required to ensure water running down the face of the window and sill is directed away from the junction with the wall.

G **Primary water seal.** Provision should be made for **drainage** of any water in the cavity through weep holes etc.

A.2.4 Curtain wall interface with EWIS, framed back wall (uninsulated)

This detail (*Figure A.2.4*) shows a typical interface of an EWIS built-up wall with a curtain wall system. The built-up wall system has a framed back wall which is uninsulated and includes a drained cavity.



A Internal membrane (if required)

B Internal membrane flashing (if required)

C Sealant joint/tape

D Membrane (if required)

E Drained cavity

F Flashing/membrane between curtain wall frame and sheathing

G Sealant joint/tape

Figure A.2.4 – Curtain wall interface with EWIS, framed back wall (uninsulated)

A The internal membrane should be **vapour resistant**, which installed correctly, will function as a **vapour control layer** and the **air barrier**.

B A membrane flashing may be installed between the curtain wall frame and the internal lining. If the flashing is to be joined to another membrane, a suitable adhesive must be used, and a sufficient overlap provided.

C A suitable seal is required between the lining and the back of the curtain wall frame to ensure continuity of the **air/vapour barrier**. This joint has to be compatible with the adjacent materials and be designed to accommodate the differential movement which will occur between the back wall and the curtain wall. This may consist of a tape or wet-applied sealant, with or without a membrane seal between the two systems.

D A **vapour resistant membrane** in this position can function as a **vapour control layer**, **water barrier** and **air barrier**. This is the most robust construction.

As a minimum requirement the sheathing boards should be water resistant and the joints between the boards robustly sealed. This will then act as the air and water barrier, however will not be as robust as including an appropriate membrane on the outer face of the sheathing. Consideration must be given to the position of the **vapour control layer**.

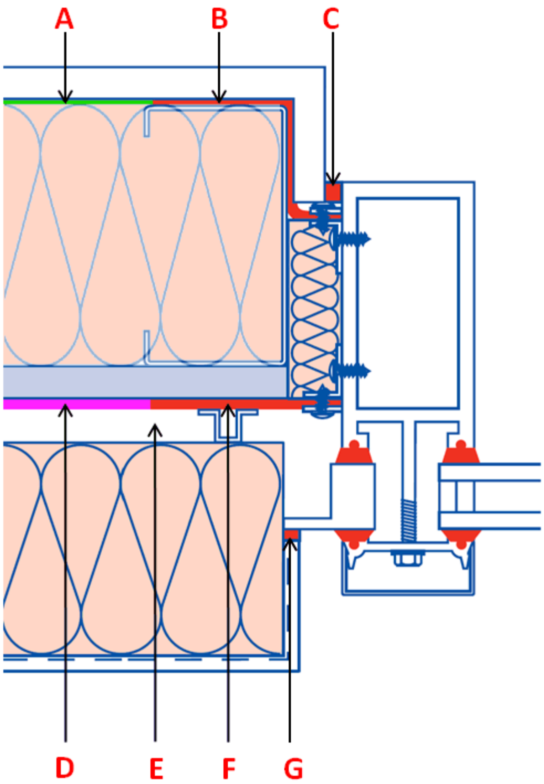
E **Drained cavity**

F Flashing/membrane if required as before/**secondary water seal**

G **Primary water seal**

A.2.5 Curtain wall interface with EWIS, framed back wall (insulated)

This detail (*Figure A.2.5*) shows a typical interface of an EWIS built-up wall with a curtain wall system. The built-up wall system has a framed back wall which is insulated and includes a drained cavity.



A	Internal membrane (if required)
B	Internal membrane flashing (if required)
C	Sealant joint/tape
D	Membrane (if required)
E	Drained cavity
F	Flashing/membrane between curtain wall frame and sheathing
G	Sealant joint/tape

Figure A.2.5 – Curtain wall interface with EWIS, framed back wall (insulated)

A The internal membrane should be **vapour resistant**, which if installed correctly, will function as a **vapour control layer** and the **air barrier**.

B A membrane flashing may be installed between the curtain wall frame and the internal lining. If the flashing is to be joined to another membrane, a suitable adhesive must be used, and a sufficient overlap provided.

C A suitable seal is required between the lining and the back of the curtain wall frame to ensure continuity of the **air/vapour barrier**. This joint has to be compatible with the adjacent materials and be designed to accommodate the differential movement which will occur between the back wall and the curtain wall. This may consist of a tape or wet-applied sealant, with or without a membrane seal between the two systems.

D If the **dew point** is within the back wall, a **breather membrane** should be used in this position. A VCL will result in **interstitial condensation**.

If the dew point is within the external insulation, a VCL can be used as before.

As a minimum requirement the sheathing boards should be water resistant and the joints between the boards robustly sealed. This will then act as the air and water barrier, however will not be as robust as including an appropriate membrane on the outer face of the sheathing. Consideration must be given to the position of the **vapour control layer**.

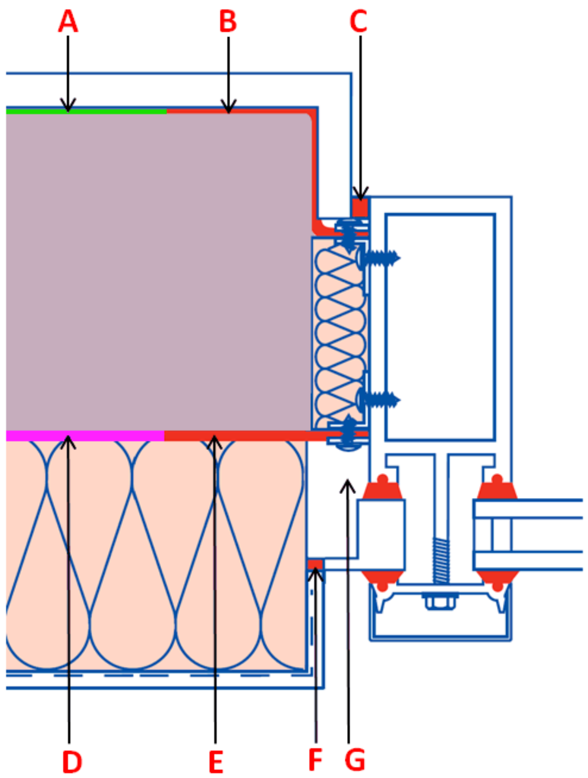
E **Drained cavity**

F Flashing/membrane if required as before/**secondary water seal**.

G **Primary water seal.**

A.2.6 Curtain wall interface with EWIS, solid back wall, no cavity

This detail (*Figure A.2.6*) shows a typical interface of an EWIS built-up wall with a curtain wall system. There is a solid back wall and there is no cavity within the wall build-up.



A	Internal membrane (if required)
B	Internal membrane flashing (if required)
C	Sealant joint/tape
D	Membrane (if required)
E	Flashing/membrane between curtain wall frame and sheathing
F	Sealant joint/tape
G	Drained cavity

Figure A.2.6 – Curtain wall interface with EWIS, solid back wall, no cavity

A The internal membrane should be **vapour resistant**, which if installed correctly, will function as a **vapour control layer** and the **air barrier**.

A **plastered surface** may form the **air barrier** and will **limit vapour transfer.**

B A membrane flashing may be installed between the curtain wall frame and the internal lining. If the flashing is to be joined to another membrane, a suitable adhesive must be used, and a sufficient overlap provided.

C A suitable seal is required between the lining and the back of the curtain wall frame to ensure continuity of the **air/vapour barrier**. This joint has to be compatible with the adjacent materials and be designed to accommodate the differential movement which will occur between the back wall and the curtain wall. This may consist of a tape or wet-applied sealant, with or without a membrane seal between the two systems.

D EWIS is most likely to be fitted to a solid wall in a **refurbishment**. The exact requirements for a membrane in this position will depend on the nature and condition of the back wall.

If the back wall is watertight, the insulation could be applied directly.

If a membrane is required, the position of the dew point should be established as before.

Consideration must be given to the position of the **vapour control layer**.

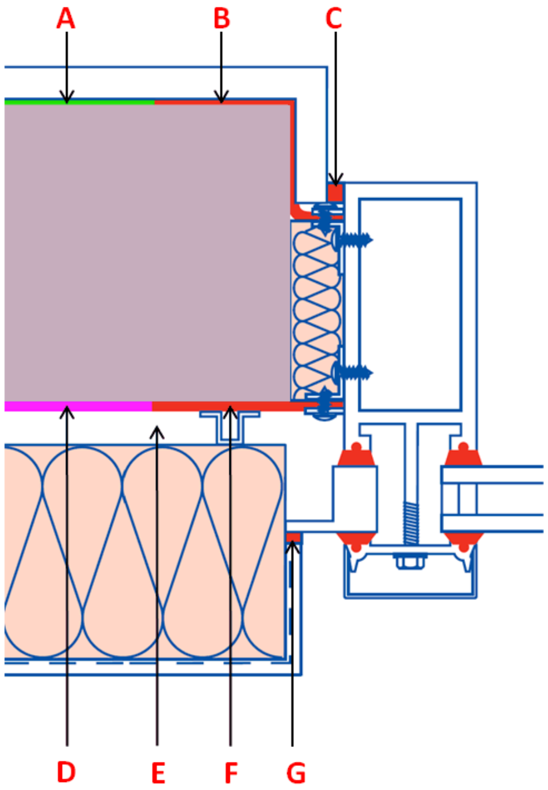
E Flashing/membrane if required as before/**secondary water seal**.

F **Primary water seal.**

G **Drained cavity.** Even if there is no drainage cavity between the insulation and the back wall, it is still recommended that the interface between the wall and frame is drained, since this is a potential weak point in terms of water penetration.

A.2.7 Curtain wall interface with EWIS, solid back wall, cavity

This detail (*Figure A.2.7*) shows a typical interface of an EWIS built-up wall with a curtain wall system. There is a solid back wall and there is a drained cavity within the wall build-up.



A	Internal membrane (if required)
B	Internal membrane flashing (if required)
C	Sealant joint/tape
D	Membrane (if required)
E	Flashing/membrane between curtain wall frame and sheathing
F	Sealant joint/tape
G	Drained cavity

Figure A.2.7 – Curtain wall interface with EWIS, solid back wall, cavity

A The internal membrane should be **vapour resistant**, which installed correctly, will function as a **vapour control layer** and the **air barrier**.

A **plastered surface** may form the **air barrier** and will **limit vapour transfer.**

B A membrane flashing may be installed between the curtain wall frame and the internal lining. If the flashing is to be joined to another membrane, a suitable adhesive must be used, and a sufficient overlap provided.

C A suitable seal is required between the lining and the back of the curtain wall frame to ensure continuity of the **air/vapour barrier**. This joint has to be compatible with the adjacent materials and be designed to accommodate the differential movement which will occur between the back wall and the curtain wall. This may consist of a tape or wet-applied sealant, with or without a membrane seal between the two systems.

D EWIS is most likely to be fitted to a solid wall in a **refurbishment**. The exact requirements for a membrane in this position will depend on the nature and condition of the back wall.

If the back wall is watertight, a waterproof membrane may not be required, however fitting an appropriate membrane will make the wall more robust.

If a membrane is required, the position of the dew point should be established as before.

Consideration must be given to the position of the **vapour control layer**.

E Flashing/membrane if required as before/**secondary water seal**.

F **Primary water seal.**

G **Drained cavity**, it is recommended that the interface between the wall and frame is drained, since this is a potential weak point in terms of water penetration.