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PROFILED METAL ROOFING DESIGN GUIDE

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THE METAL CLADDING & ROOFING MANUFACTURERS ASSOCIATION

The Building Envelope Authority

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For up to date information on metal roof and wall cladding, including downloadable construction details, visit **www.mcrma.co.uk.**

Typical construction and assemblies

1.1 Introduction

Profiled steel or aluminium sheets are used in various roof constructions as shown below. The guidance in this document applies in principle to all of these constructions, but primarily to the double skin system with trapezoidal or secret fix profiled sheets, which is the most common type of metal roof construction used in the UK. Sinusoidal profiles (for example corrugated iron) are not used for modern industrial and commercial roofs and they are not covered by this guide. Secret fix systems and composite panels are both described fully in separate MCRMA technical guides. The guidance in this document is generally consistent with that in BS5427 *The Code of Practice for the use of Profiled Sheet for Roof and Wall Cladding on Buildings*.

1.2 Single skin system

An uninsulated profiled metal sheet fixed directly to the purlins.

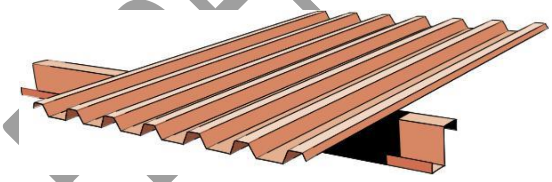

Fig 1: Single skin system

1.3 Double skin system

This common type of construction consists generally of a shallow profiled metal liner, a spacer system and an outer sheet usually in a deeper profile. The insulation is typically a mineral fibre quilt.

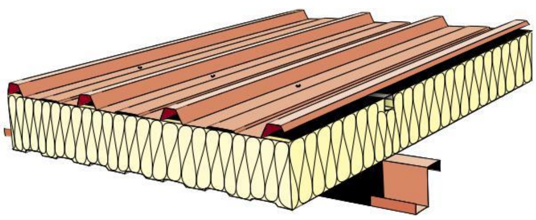

Fig 2: Double skin system

1.4 Secret fix

Secret fix or standing seam systems use special profiles for the weather sheet with virtually no exposed through fasteners. This provides greater reliability and means they can be used on very low slope roofs. Secret fix sheets can be used as the weather sheet in all the roof constructions shown.

NOTE: For detailed information see MCRMA technical paper No 3 *Secret fix roofing design guide*

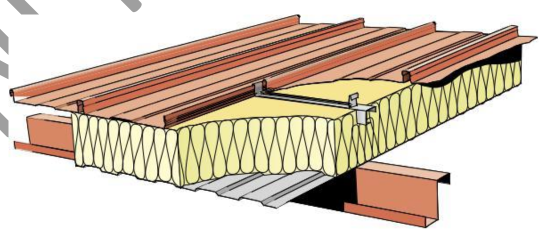

Fig 3: Secret fix system

1.5 Site-assembled composite

This is a special site-assembled double skin construction which uses profiled rigid insulation to completely fill the space between liner and weather sheets. The insulation may be polyurethane, polyisocyanurate or mineral fibre. No spacer systems are required.

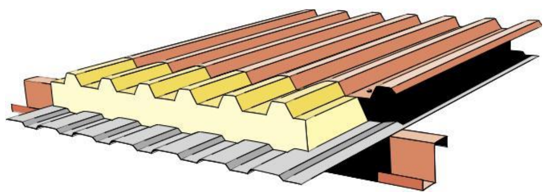

Figure 4 – Site-assembled composite

1.6 Factory made composite panels

These panels combine a liner, rigid insulation and weather sheet in a single factory made component. Although it is possible to use various types of rigid insulation only polyurethane and polyisocyanurate expand and autohesively bond to the facings during manufacture and they are therefore used for the majority of composite roof panels.

Components

NOTE: For detailed information see MCRMA technical paper No 9 *Composite roof and wall cladding design guide*

Fig 5: Factory made composite panel

1.7 Under-purlin lining

Note that where under-purlin lining is required for hygiene reasons, for example in food processing buildings, an additional liner must be used in conjunction with a standard over-purlin Insulated cladding system.

Steel and aluminium roofing sheets are produced by MCRMA members in a wide variety of profile shapes, coatings and colours. The details below are for general guidance and full details of products should be obtained from the individual manufacturers. Component and system durability is discussed in Section 9.0.

2.1 Profiled sheets

Profiled weather and liner sheets are made of steel to BS EN 10147 or aluminium to BS EN 485 (and related standards).

Thicknesses vary depending on product and application but the values in Fig 6 are generally regarded as minimum values in mm.

	STEEL	ALUMINIUM
Weather sheet	0.7	0.9
Liner sheet	0.4	0.5
Walkable liner sheet	0.7	0.9

Fig 6: Minimum sheet thicknesses

The depths of trapezoidal profiles are typically 32mm for the weather sheet and 20mm for the liner, but note that the weather sheet depth in particular might vary considerably. Cover widths vary similarly but are often about 1m.

�� Coatings

All steel faces are hot dip galvanised or aluzinc coated and painted to provide the required appearance and durability. Aluminium is supplied with a mill or painted finish.

The coatings shown in Fig 7 are commonly available in a wide range of colours. Individual manufacturers may supply others.

Type	Substrate	Typical thickness: microns	Application
Plastisol	steel	200	weathersheet
Pvf2	steel and aluminium	25	weathersheet
Multicoat	steel and aluminium	100	weathersheet
ARS	aluminium	28	weathersheet
Polyester	steel and aluminium	22	liner

Fig 7: Typical coatings

NOTE: The standard liner specification is for normal internal environments. Higher specification coatings should be used where there are aggressive environments or where hygienic finishes are required.

Full details of the range of available coatings can be obtained from the individual manufacturers.

Spacer systems

The spacer system in a double skin metal roof is used to create a cavity between the liner and weather sheet for the layer of insulation. The spacers are structural items, which support the weather sheet and they are always positioned over purlins or other structural members and must be fixed securely to them.

Zed spacers (or minizeds) made of galvanised steel approximately 1.5mm thick and supported on nylon ferrules were the standard solution for many years. They are generally suitable for layers of insulation up to 100mm thick but at greater depths the traditional zed/ferrule arrangement is not adequately stiff or stable.

A new generation of spacers consisting of roll formed rails of structural grade steel with plastic blocks or bracket supports and thermal break/ vapour seal pads have been developed and are now commonly used. These are generically known as rail and bracket systems. The designs are engineered to be more stable at a range of depths to suit most insulation thicknesses likely in the future, and they also minimise thermal bridging. Typical spacer systems are shown in Fig 8.

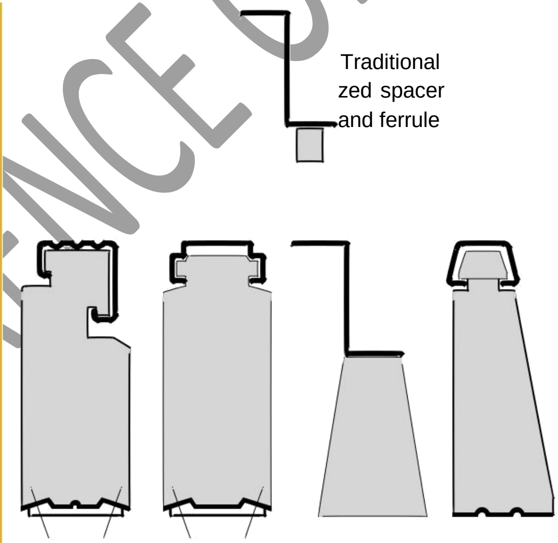

Fig 8: Typical spacer systems

Fasteners

There are many proprietary fasteners available and it is not possible to describe them all in this guide. The details below are for general guidance. For detailed information see MCRMA technical paper No 12 *Fasteners for metal roof and wall cladding: design, detailing and installation guide*. Further specific details can be obtained from the cladding and fastener manufacturers.

Fasteners can be divided into two distinct categories:

a) Primary

These fasteners are designed to transfer all loads on the cladding system back to the supporting structure so their strength is particularly important. If the fasteners are exposed they must also provide a weathertight seal. They are normally used in the valley of the profile. If crown fixing is recommended by the manufacturers, saddle washers are usually required.

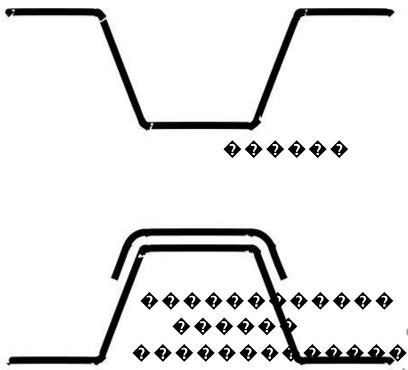

Fig 9: Typical primary fastener positions

The most common fasteners are self-drilling and self-tapping which can be installed in one simple operation into a variety of materials. Self-tapping screws (with no drill point) are also available and may be preferred in some applications. Most screws are now available in plated carbon steel or stainless steel, they come complete with a 16mm or 19mm diameter sealing washer and they can have integral colour matched plastic heads or separate push-on plastic caps. The strength of a fixing depends on the fastener design and the thickness and yield strength of the purlin. Fastener manufacturers and suppliers can supply strength data for their products installed in a range of materials and thicknesses.

b) Secondary

These fasteners are used to connect side laps, flashings etc. and they are not normally considered as structural. However, where the fasteners are providing lateral restraint or in a stressed skin design, their strength would have to be considered in the structural calculations.

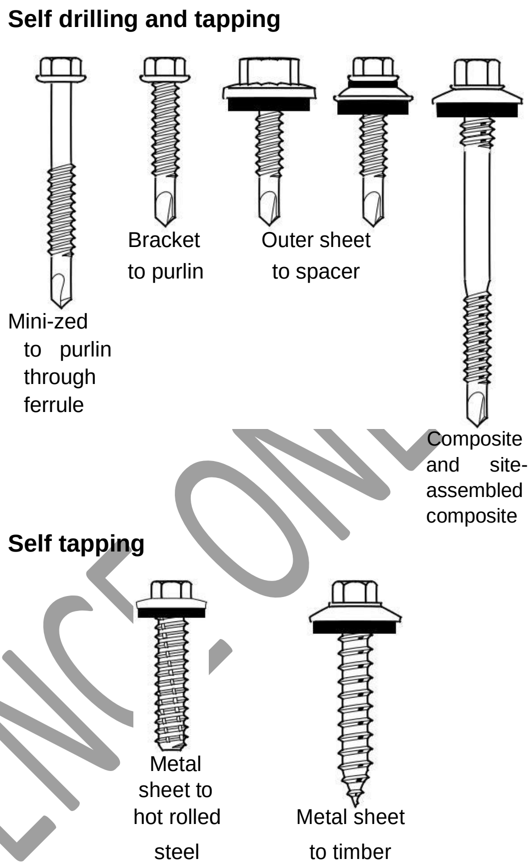

Fig 10: Primary fasteners

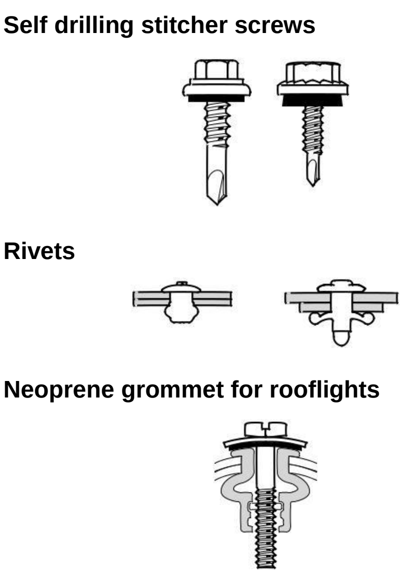

Fig 11: Secondary fasteners

In most cases these fasteners are exposed so they must provide a weathertight seal. The most common types are self-drilling and self-tapping stitcher screws with sealing washers and plastic heads/caps, or sealed rivets with or without plastic caps.

When selecting the fasteners for a roof, the structural performance, environmental conditions, corrosion resistance (including bi-metallic corrosion), weathertightness and ease of application must all be considered.

2.5 Insulation

The majority of site-assembled double skin roof constructions use mineral fibre (glass or rock) quilt insulation supplied in rolls. When unrolled on site the material expands to at least its required thickness and normally fills the cavity created by the spacer system between the liner and weather sheet. The material is normally quite soft and deforms around the small profiled ribs on the liner, and under and around the spacer system.

Rigid mineral fibre insulation slabs are also used in some circumstances but this is less deformable than the quilt and the roofing system has to be designed and installed with this in mind so that no gaps are left in the insulation layer.

Site-assembled composite constructions do not use spacer systems and rely on the rigidity of the insulation and special fasteners to support the outer sheet. In this case rigid profiled polyurethane, polyisocyanurate, and mineral fibre insulation are used.

3.1 Performance requirements

The effects of the internal and external conditions on roof constructions are more severe than on wall cladding. The satisfactory performance of any roof cladding system depends on the correct selection of materials, and the design, detailing and assembly of every aspect of the construction. The position and shape of the building, all types of loading and the internal and external environments must all be considered.

3.2 Roof pitch

Over recent years roof pitches on industrial and commercial buildings have tended to be as shallow as possible in order to reduce the heating costs of the large empty roof spaces, and for aesthetic reasons. Most through fixed trapezoidal metal roof sheets incorporating normal side and end laps are suitable for roof pitches of 4° or steeper. Note that the risk of leakage decreases as the pitch increases. For increased reliability and for pitches down to I ° (after all deflections), a secret fix system must be used with no exposed through fasteners, special side laps and preferably no end laps.

NOTE: For detailed guidance refer to MCRMA technical paper No 3 *Secret fix roofing design guide*.

3.3 End laps

The standard end lap arrangement for trapezoidal steel weather sheets at any roof pitch greater than or equal to 4° is shown in Fig 12. Typically, two continuous runs of 6 × 5 or 6mm diameter butyl sealant strips are used. The lower run is the primary weather seal and should be positioned as close as possible to the edge of the top sheet. The upper seal is to prevent moisture entering the overlap from inside the cavity.

The fasteners clamp the two sheets directly to the spacer (or rigid insulation) and both runs of sealant are compressed. The frequency of the fasteners depends on the profile but must be sufficient to consistently clamp the sheets and seals along the full length, typically every trough. For optimum durability the edge of the overlapping sheet must be painted.

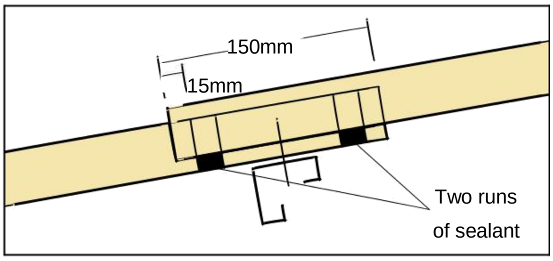

Fig 12: End lap detail for roof pitches greater than 4°

Aluminium weather sheets may require a slightly different end lap arrangement to allow for the coefficient of linear expansion, which is twice that of steel. The actual arrangement will depend on the length and colour of the sheets. The colour determines the maximum temperature that the sheets reach and therefore the maximum degree of expansion.

Fig 13 shows a typical detail, which allows some movement at the end lap joint without affecting the fasteners. Special sealants need to be used to provide a suitable sliding joint, and the overlap may be increased to 200mm. When aluminium profiles are being considered the manufacturer's recommendations should be followed.

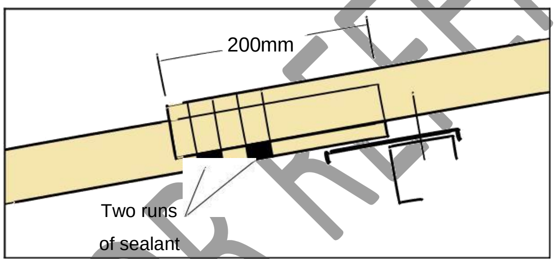

Fig 13: End lap detail to allow some movement in the joint

For increased reliability the number of end laps should always be minimised as far as possible.

- **Side laps**

A typical side lap between trapezoidal sheets is shown in Fig 14. This arrangement is ideal because the outer rib of the underlapping sheet is complete and provides the optimum support for the overlapping sheet so that the side lap can be sealed and stitched effectively.

It is common to see specifications recommending that side laps should be arranged away from the prevailing wind. This is sensible in principle but is often not practical. The joint must be weathertight in all circumstances.

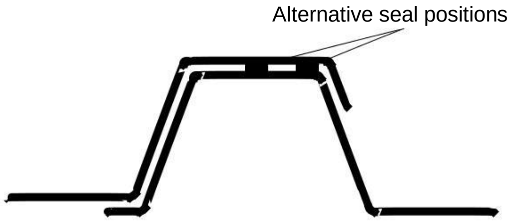

Fig 14: Typical side lap detail

Typically, a continuous run of 6 × 5 or 6mm diameter butyl sealant strip is used on the centre of the underlapping rib or on the weather side of the lap on all trapezoidal sheets. All trapezoidal roof sheets should be stitched through the centre of the top of the side lap at typically 450mm centres using sealed stitcher screws or rivets.

Thermal Performance

4.1 Regulations

The thermal performance of the roof cladding is important because it affects the amount of energy required to heat the building and will influence the running costs and the comfort of the occupants. Approved Document L2 to the Building Regulations (2002 Edition) *Conservation of Fuel and Power* defines the required levels of performance in terms of U values, thermal bridging, and air tightness, and explains how the requirements can be achieved. Site testing of the completed building is required in many cases, to ensure the design performance has been achieved. It means that the building designer and cladding contractor need to pay more attention to the thermal performance of individual details of the construction, which were not previously defined.

The Approved Document refers to MCRMA technical paper No 14 *Guidance for the design of metal roofing and cladding to comply with Approved Document L2:2001*, for further more detailed information.

4.2 U-values

4.2.1 Methods of determining U-values

The elemental U-value or thermal transmittance specified in Approved Document L2 for industrial and commercial roofs is 0.25 W/m^2K.

Approved Document L2 requires that profile shapes, and repeating thermal bridges, such as metal spacers and other fixings, are taken into account when a U-value is calculated using the 'combined' method, which is specified in BS EN ISO 6946[1] and CIBSE Guide A3[2]. However, this method is designed to deal with the type of thermal bridges such as timber studs, which distort the heat flow relatively little, and it specifically excludes elements in which the insulation layer is crossed by thin metal components.

Ultimately, the U-value of this type of element has to be calculated by developing a full two- or three-dimensional thermal model of the structure to calculate the heat flows. This is a complex task requiring software, which complies with BS EN ISO 10211:1996[3], and is usually carried out only by specialist consultants. A number of system manufacturers provide U-values of their systems for different insulation thicknesses, fixing spacings, etc that have been calculated by independent bodies.

A range of simplified methods has been developed for use in specific cases; these can be obtained from the following sources:

- Twin-skin systems with zed spacers are covered in BRE Information Paper IP 10/02[4].
- Twin skin systems with rail and bracket spacers are covered in SCI Technical Information Sheet P312[5].
- A software package KOBRA, which allows the calculation of the thermal properties of a range of wall and roof systems is used by members of the MCRMA.
- A U-value calculator, which covers all types of walls, roofs and floors, is available and can be downloaded from http://projects.bre.co.uk/ uvalues/.

The appropriate methods that should be used to calculate U-values in all instances are specified in BRE Report BR443[6].

Alternatively the thermal transmittance (U) of a roof cladding construction can be measured using a calibrated hot box, in accordance with EN ISO 8990.

4.2.2 Insulation thickness required

The following table indicates the approximate insulation thicknesses required to achieve a U-value of 0.25 W/m^2K using a typical type of rail and bracket, liner and outer sheet. The effect of different insulation materials and varying purlin and bracket centres is also indicated.

		Purlin spacing : m		
Insulation conductivity : W/mK	**Bracket spacing : m**	**0.9**	**1.4**	**1.8**
0.035	0.5	175	160	155
	1.0	160	150	150
0.04	0.5	210	195	185
	1.0	190	180	175
0.045	0.5	220	210	200
	1.0	205	200	195

Fig 15: Insulation thickness in mm necessary to achieve a U-value of 0.25 W/m^{2}K

(Assuming a liner sheet with 18mm profiles at 200mm centres and an outer sheet with 35mm profiles at 167mm centres)

These are the theoretical minimum insulation thicknesses required. In practice, the insulation quilt used is normally selected from a range of standard thicknesses such as 80mm, 100mm etc. and a building might contain a variety of purlin spacings so the construction and materials have to be specified with care.

No matter which insulation is used it is vital that the material is installed carefully throughout, ensuring there are no gaps particularly at apertures, ridge, eaves, corners etc. The continuity of insulation is specified in the Regulations, and a thermographic survey might be used to check the consistency of the insulation in the completed building. Individual manufacturers' literature provides details of their systems.

In some cases it may only be necessary for the roofing supplier to demonstrate that the system U-values are less than or equal to the value of 0.25 W/m^{2}K required in Approved Document L2. However a more detailed knowledge of the specific U-values of all the elements of the building will be necessary if it is proposed to trade off areas, assess the contribution of thermal bridges or trade off heating system efficiency with improved fabric performance (see below). In these cases it will be necessary for some member of the design team, generally the architect, to take responsibility for collating the heat loss from all the plane areas (U-values), and thermal bridges at junctions between the plane areas (-values), and dimensions of the individual components, from a number of different suppliers.

4.2.3 Trading off U-values and areas

Within certain constraints, Approved Document L2 allows trading between the elemental U-values and the areas of components specified in the Approved Document, provided that the overall heat loss from the building is less than that from a notional building of the same size and shape, with the elemental U-values and areas.

The various constraints are:

- The U-value of any opaque part of a roof is no worse than 0.35 W/m^{2}K.
  This constraint is designed to reduce the risk of surface condensation. It accommodates situations, such as the need to include more fixings, which raise the U-value, in areas of a

roof subject to greater wind uplift. The area weighted average U-value of the roof should meet the 0.25 W/m^2K limit.

- If the area of openings in the proposed building is less than the values shown in the Approved Document, the area weighted average U-value of the opaque parts of the roof cannot exceed the appropriate value in Table 1 of Approved Document L2 by more than 0.02 W/m^2K.
- No more than half the allowable rooflight area can be converted into an increased area of windows and doors.

The possibilities for trading off and the constraints may be illustrated by some specific examples:

A) Table 1 of Approved Document L2:2002 gives the elemental U-values for a roof with integral insulation as 0.25 W/m^2K and for rooflights as 2.2 W/m^2K. Table 2 gives the maximum allowable roof light area as 20%. This means that the average U-value for the roof will be $0.8 \times 0.25 + 0.2 \times 2.2 = 0.64$ W/m^2K.

If the rooflight area was only 10%, the rooflight U-value could be increased to U_{rl} so long as the relationship: $0.9 \times 0.25 + 0.1 \times U_{rl}$ δ 0.64 was satisfied. This means that U_{rl} can be as high as 4.1 W/m^2K. It is not, however possible to carry out the similar calculation: $0.9 \times U_{rf} + 0.1 \times 2.2$ δ 0.64 to allow a U-value of the opaque parts of the roof up to 0.47 W/m^2K; constraint b), above, limits this to 0.27 W/m^2K.

B) If, for structural reasons, more fixings are used near the eaves and ridge, raising the U-value of 25% of the opaque area of the roof to 0.35 W/m^2K, the maximum allowed by constraint a), the U-value of the remaining 75% of the opaque part of the roof has to be reduced to satisfy: $0.75 \times U_{rf} + 0.25 \times 0.35$ δ 0.27, i.e. to 0.24 W/m^2K.

4.2.4 Responsibility for calculation of U-values

The U-values of the individual components of a building should be specified during the design stage. These will often follow the elemental values specified in Table 1 of Approved Document L2, however there may be circumstances in which lower (better) values may be specified in certain areas to allow trading off with other areas. The responsibility for calculating the U-values of cladding systems usually lies with the supplier of the system, who should be in a position to justify the values quoted by reference to the documentation discussed above or by producing results from calculation carried out to BS EN ISO 6946 or BS EN ISO 10211-1 as appropriate. The values for other cladding elements such as smoke vents or rooflights should be provided by the appropriate manufacturer.

4.3 Thermal bridging

4.3.1 Effects of thermal bridging

Thermal bridges are areas of the fabric where the geometry of the structure and/or the presence of high conductivity materials crossing the insulation lead to heat flows that are locally higher than in surrounding areas. These both add to the total energy demand of the building and lower the internal surface temperatures. Depending on the environmental conditions within the building and the nature of the internal surfaces this can lead to surface condensation or, less commonly in industrial buildings, mould growth.

Approved Document L2 requires that the building fabric should be constructed so that there are no significant thermal bridges or gaps in the insulation layer(s) within the various elements of the fabric, at the joints between elements and at the edges of elements such as those around window and door openings. Thermal bridging within elements, such as at spacers, is taken into account when calculating U-values, so here it is necessary to concentrate on the thermal bridging at junctions and penetrations. One way of demonstrating compliance is to utilise details and practice that have been independently demonstrated as being satisfactory. This can be done for domestic style constructions by following the details given in the robust construction details publication. However, as these often do not apply to industrial buildings, calculations or the use of robust design practices must be used to demonstrate compliance. BRE IP 17/01[7] and the MCRMA technical paper No 14[8] specify the necessary procedures.

4.3.2 Design to avoid condensation and mould growth

In buildings, especially housing, which have absorbent internal surfaces, the lowered surface temperatures at thermal bridges can cause mould growth, which is a major cause of respiratory allergies such as asthma. Mould growth, which occurs at a surface relative humidity of 80%, is, however, very rare on the impermeable internal surfaces of metal faced roofs. Condensation, depositing drops of water on the surface, which does not occur until the surface relative humidity has reached 100%, is much more likely in this case. Even when condensation occurs, often less than 10 grams per square metre accumulate, seen as a fine mist on the surface, which rapidly disperses as temperatures rise. At least 70 g/m^2 must accumulate before it will run down a sloping surface and 150g/m^2 before dripping will occur from a horizontal surface.

The concept of surface temperature factor, or f-value, is used to separate the performance of the structure from the imposed environmental conditions; this is defined by:

$$f = \frac{Ts - Te}{Ti - Te}$$

where Ts is the local surface temperature
Te is the external air temperature
Ti is the internal air temperature.

Surface temperature criteria, which define f_{min} and which are more appropriate to industrial buildings have been established based on BS EN ISO 13788:2001[9]. Different building types fall into the different classes shown in Fig 16, with the minimum f-values, which are required to avoid condensation in the different internal environments.

The f-value for a particular construction can be established by computer modelling, as part of the heat loss calculation (see 4.3.4).

4.3.3 Design to reduce heat loss through thermal bridges

Heat loss through linear thermal bridges (at junctions and openings) is expressed in terms of the linear thermal transmittance or -value (pronounced 'psi'). This is the extra heat loss

Humidity class	Building type	Minimum f-value
1	Storage areas	0.30
2	Offices, shops	0.50
3	Dwellings with low occupancy	0.65
4	Dwellings with high occupancy, sports halls, kitchens, canteens; buildings heated with un-flued gas heaters	0.80
5	Special buildings, e.g. laundry, brewery, swimming pool	0.90

Fig 16: Internal humidity classes and the minimum temperature factor necessary to prevent condensation

through the junction, over and above the heat loss through the adjoining plane elements.

BRE IP 17/01 contains a table of -values for thermal bridges in typical domestic constructions; if the calculated -values in the building under design are less than or equal to these values, then no further action is necessary. If the thermal bridges under investigation do not appear in this table, which is most likely in the case of industrial buildings, the total heat loss for the building fabric must be calculated, and compared with the permitted maximum heat loss from a notional building with the same size and shape.

The permitted heat loss through thermal bridges is 10% of the sum of the heat loss through the plane areas of the notional building. So to satisfy the Regulations:

$$A_{ac} \cdot U_{ac} + L\cdot < 1.1 \times A_{el} \cdot U_{el}$$ Where:

A_{ac} and U_{ac} are the elemental areas and U-values of the real building.

L· is the sum of the heat loss through junctions.

A_{el} and U_{el} are the elemental areas and U-values of a notional building with the same size and shape as the real building.

The fact that the heat loss from the real building is compared with that from the notional building means that, provided that the surface temperature criteria in Fig 16 are met, it is possible to trade off areas and U-values against thermal bridges. So that if it was not possible to design out a severe thermal bridge, the criterion could, for example, be met by reducing the rooflight area from 20%, while retaining the rooflight U-value at 2.2 W/m^2K. (See example in MCRMA technical bulletin No 11).

The calculation of -values and f-values is not required by Scottish Technical Standard J.

4.3.4 Sources of -values and f-values

Because thermal bridges occur at junctions, complex two dimensional calculations using software that complies with BS EN ISO 10211-1:1996 are needed to determine the -values and f-values. These can be carried out by specialist contractors, but are time consuming and expensive. A number of manufacturers have commissioned calculations of the necessary values and publish them in catalogues of standard details. These are generally accepted by building control authorities. There are however, no generally accepted conventions for carrying out these calculations, and it is possible that cases of dispute will arise.

While cladding suppliers can generate the necessary thermal bridge parameters for their systems, there may be particular difficulties where different systems meet, for example where a twin skin roof from one manufacturer meets a composite panel wall from another. In these cases it will be necessary for the building designer/ architect to arrange for the -values and f-values to be calculated for the particular instance.

Calculating the total heat loss for the building requires information on the areas and U-values, and details of junctions of all the various components of the building, which will have been provided by a number of suppliers and trades. This means that realistically it can only be done by the building designer/architect.

Some typical junction details for twin skin metal roofing are shown in section 11. Many of these have no additional metal crossing the layer of insulation and the insulation is effectively continuous, and as a result the values are very low. Any details which incorporate these design principles would be expected to have low values, and contribute very little to the total heat loss from the building.

4.4 Air leakage

Besides the fabric heat loss through the plane areas and thermal bridges, described in sections 4.2 and 4.3, air leakage from the interior can add very significantly to the total energy demand of a building. Ventilation heat loss can account for as much as 50% of the total heat loss from a leaky building, leading to a significant potential for savings if the leakage paths are identified and sealed. A further disadvantage of very leaky buildings is that their internal environment is difficult to predict and control, leading either to plant oversizing or to uncomfortable conditions within the building.

Approved Document L2: 2002 lays stress on the need to achieve a reasonable standard of airtightness, and makes suggestions as to how this might be achieved by appropriate sealing measures. It also suggests that it may be necessary to demonstrate compliance with a report from a ‘competent person’ that appropriate design details and building techniques have been used or, for buildings larger than 1000 m^2 floor area, to carry out an air leakage test. It is, however, important to remember that the cladding system is only one of the areas of the building envelope that contribute to the leakage. Junctions and openings such as doors, loading bays, windows, rooflights, smoke vents and service penetrations may be more important.

4.4.1 Methods for measuring airtightness

Techniques for the testing and analysis of the air leakage of buildings are described very fully in CIBSE Guide TM23, which should be consulted for fuller information. An air leakage test is carried out by mounting a fan (or fans) in a suitable aperture within the building envelope, usually a doorway, running the fan to blow air into the building creates a pressure difference across the building envelope – see Fig 17 and Fig 18. The fan speed is varied to create a range of pressure differences up to about 50 Pa (1Pa = 1N/m^2) and the flow rate recorded at each stage. The flow rate at 50 Pa, Q_{50}, normally in m^3/h, which is found from a plot of the flow rate against pressure difference, is reported as the parameter which defines the 'leakiness' of the building.

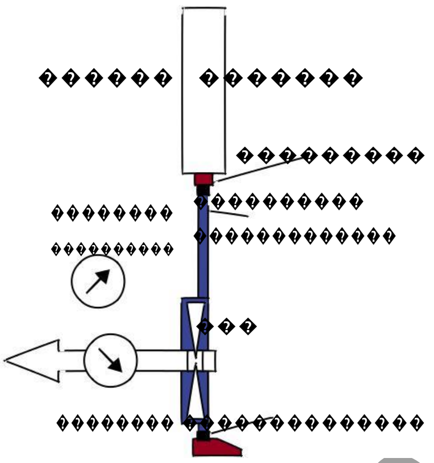

Fig 17: Diagrammatic representation of whole building leakage test

Fig 18: Large fan for testing industrial buildings

A pressure test relies on the assumption that the pressure difference is uniform over the entire building envelope. This imposes certain restrictions on the external climate parameters that prevail during the test. Ideally the internal to external temperature difference should be less than 10°C and the wind speed should be less than 3 m/s. Higher temperature differences lead to high stack pressure differences that distort the test results, especially in very tall buildings, and high wind speeds cause random pressure differences, which make accurate readings difficult.

During a test, all internal doors should be wedged open and, where appropriate, combustion appliances must be switched off and any open flues and air supply openings temporarily sealed (flues from room-sealed appliances, such as balanced flues in domestic appliances, do not need to be sealed). External doors and other purpose-made openings in the building envelope should be closed and mechanical ventilation systems turned off, with the inlet and outlet grilles sealed. Fire dampers and ventilation louvres should be closed. Drainage traps should contain water.

The cladding or roofing system is only one of the possible leakage routes from a building and a simple fan pressurisation test quantifies the total air leakage of a building, but does not directly identify the leakage paths. A number of methods can be used to provide more information, including releasing smoke from smoke pencils or puffers to visualise specific flow paths; an internal infra-red survey of a depressurised building in cold weather will rapidly reveal areas that are being chilled by incoming air; repeated testing of a building as successive specific components are sealed, and isolating and testing specific components.

4.4.2 Required air tightness

The parameter that is specified in Approved Document L2 to quantify the air leakage rate through the building envelope is the air permeability. This is measured by the fan pressurisation technique and is expressed in terms of the volume flow of air per hour (m^3/h) supplied to the space, per square metre (m^2) of building envelope (including the ground floor area) for a specified inside to outside pressure difference of 50 Pa.

Section 2.4 of Approved Document L2 requires that the air permeability should be less than 10 m^3/h/m^2 at 50 Pa.

Interstitial condensation

• ***Important leakage routes***

To minimise air leakage through twin skin metal roofing, the liner side of the construction must be sealed as effectively as possible. This involves sealing:

- Liner end laps – typically with butyl sealant strip and additional fasteners
- Liner side laps and side joint at perimeter – typically with a wide butyl faced tape
- Fasteners – with normal washers
- Perimeter or ends of sheets – with profiled liner fillers and additional fasteners
- Any penetrations – such as pipes

With a good standard of construction and good attention to detail it is easy to achieve a twin skin metal roof structure that is tight enough to pass the Approved Document L2 criterion.

However, as noted above, the cladding system is only one of the areas of the building envelope that contribute to air leakage. Junctions and openings such as doors, loading bays, windows, rooflights, smoke vents and service penetrations, may be more important.

The typical junction details shown in section 11 indicate where air seals have to be fitted, but reference should be made to manufacturers' information for details of their particular systems. In every case, satisfactory sealing will only be achieved by good workmanship on site.

Interstitial condensation means condensation that occurs inside a construction, usually hidden from view. In normal metal clad industrial building applications it is not an important issue, but in some more specialist applications it can be a critical issue.

5.1 Risks of interstitial condensation

Interstitial condensation may occur if water vapour, generated within the building, is able to penetrate the liner and reach cold areas outside the insulation, where it may condense, usually on the outer sheet. If sufficient condensation occurred, it could potentially cause problems such as corrosion of metal components and wetting of thermal insulation, and the condensate could run into the building staining internal finishes or dripping onto equipment or processes. Because of the inherent impermeability of metal liners, these problems do not occur in normal applications.

Small amounts of condensate, 0 – 10 g/m^2, a fine mist, will commonly occur on most nights, even in the summer, however these will usually evaporate rapidly during the day, without leading to any long term accumulation. Problems will occur when the rate of condensation is high enough to allow accumulations sufficient to cause running or dripping of the condensed water.

The risks of interstitial condensation depend on the design and construction of the roof, and the internal and external climate of the building. Risks will be higher in colder external climates and in buildings such as swimming pools, laundries or some food processing plant, that operate at high internal humidities. Buildings, which are operated at an over pressure, to reduce the ingress of contaminants, are at especial risk as the over pressure can drive warm moist air into the structure.

It should be remembered that, while interstitial condensation is usually caused in the UK by cold external climates, severe problems can occur in air conditioned buildings in warm humid climates, when the vapour drive is from outside to in. It is essential that designs are appropriate to the climate in which the building is situated.

General guidance for the design of structures to minimise the risks of interstitial condensation is given in BS5250:2002 and a procedure for calculating the accumulation of condensate in any climate is given in BS EN ISO 13788:2002.

5.2 Design to avoid interstitial condensation

The moisture content of the internal environment should be assessed and, if appropriate, controlled by providing the correct levels of ventilation or by air conditioning. This would normally be the responsibility of the building services engineer. However, it should be recognised that there will be some degree of moisture load in almost all building; the design of the roof structure should therefore:

- prevent water vapour reaching the cold areas of the roof structure, by including an impermeable vapour control layer on the warm side of the insulation; and
- provide means for any water vapour that does penetrate the structure to escape.

Vapour control layer

To minimise the potential for interstitial condensation in double metal skin construction the most critical part of the construction is the vapour control layer. This is used to minimise the amount of moisture vapour which can enter the construction by diffusion and air leakage. It must be positioned on the warm side of the insulation. The vapour control layer can be made by carefully sealing the profiled metal liner or by providing a separate polythene membrane on top of the liner. In either case it is essential that the vapour control layer is continuous throughout the roof and all laps are sealed, including at abutments, rooflights, penetrations, gutters, ridge etc. Note that constructing the liner to minimise air leakage (see section 4.4) will automatically provide the vapour control layer.

The same principles apply to all the other types of metal roof construction shown in section 1. All systems require attention to detail in their design and construction on site.

5.2.2. Ventilation

No matter how well the vapour control layer is constructed, some moisture vapour may get into the construction and there must be provision in the design to deal with it. The smaller the roof voids and the insulation cavity the less moisture there is likely to be present to condense. The roof voids should therefore be the minimum required and the weathersheet should be in contact with the insulation.

In site-assembled double skin constructions with standard trapezoidal sheets ventilated fillers must be used at the ridge and eaves to allow some breathing through the ribs in the profiled weathersheet. This helps to disperse any moisture vapour which is in the construction.

Other types of profiled sheets, such as secret fix, use different methods of ventilation. See individual manufacturers' details.

5.3 Breather membranes

A breather membrane is sometimes fitted on top of the insulation in site-assembled double skin constructions. This is designed to allow moisture vapour to breathe out of the construction and to prevent any condensation, which might form on the ribs of the outer sheet from dripping onto the insulation. It should be detailed to allow any water on its surface to drain down to the gutter.

Experience has shown that a breather membrane is not required in most circumstances. Its requirement depends on the building's internal environment and the application. In normal applications, provided the vapour control layer has been properly installed, the amount of condensation is likely to be small and no breather membrane is required. A breather membrane only needs to be considered when the building has a high humidity internal environment, and then it should only be used in conjunction with an effective vapour control layer and eaves to ridge ventilation through the profile ribs.

Site-assembled composite systems and factory-made composite panels with rigid foam insulation have no voids above the insulation so there is no requirement for rib ventilation or breather membranes.

5.4 Rooflights

Ensuring continuity of the vapour control layer and ventilation through profiled ribs normally means that site-assembled rooflights should be used with site-assembled double skin cladding systems. Factory-assembled rooflights are used with composite panels.

Compared to the surrounding insulated cladding, rooflights have a significantly worse thermal performance, there is therefore an increased potential for condensation at rooflights. Misting of all factory or site-assembled rooflights can be anticipated from time to time, but it generally dissipates without harmful effects. However, if condensation is unacceptable rooflights should be avoided completely.

NOTE: For detailed guidance refer to MCRMA technical paper No 1 *Recommended good practice for daylighting in metal clad buildings*.

The acoustic performance of a building can be an important aspect of the design and the roof construction can play a major role in the performance. For detailed guidance see MCRMA technical paper No 8 *Acoustic design guide for metal roof and wall cladding*. There are two potential acoustic requirements:

6.1 Sound reduction

In this case the objective is to provide sound reduction through the structure in order to reduce the airborne transmission of noise inside a building to the outside, or vice versa. The level of performance is referred to as the Sound Reduction Index (SRI), measured in decibels (dB). Increasing the SRI by 3dB will approximately halve the transmitted sound energy.

While all metal skin roofing will provide some degree of sound reduction the best performance is achieved with double skin constructions using soft mineral fibre insulation. Additional layers may be added within the construction, to further improve the performance. Generally the heavier the cladding materials the better the Sound Reduction Index. The actual performance of each cladding system also depends on the weathersheet and liner profiles and the method of assembly.

As a guide a typical site-assembled double skin steel roof cladding might achieve a weighted Sound Reduction Index (Rw) of approximately 38 dB whereas the value for a factory-made composite roof panel (rigid insulation) might be 26 dB. Individual manufacturers can provide advice on their own systems.

6.2 Sound absorption

Sound absorption is used to reduce noise levels and improve the acoustics inside a building by reducing unwanted multiple reflections from hard internal surfaces (reverberation). This can be achieved with site-assembled double skin systems by using a perforated liner and mineral fibre insulation – see Fig 19. The perforations allow the noise to enter the insulation where it is absorbed.

A typical system would include a polythene vapour control layer over a relatively thin layer of acoustic

Performance in fire

insulation, followed by the main layer of thermal insulation. The acoustic insulation should be faced with a glass fibre tissue or similar, to reduce the risk of dust falling through the perforated liner. The exact acoustic performance of a roof cladding cannot be assumed from data for a similar construction and must be determined by test.

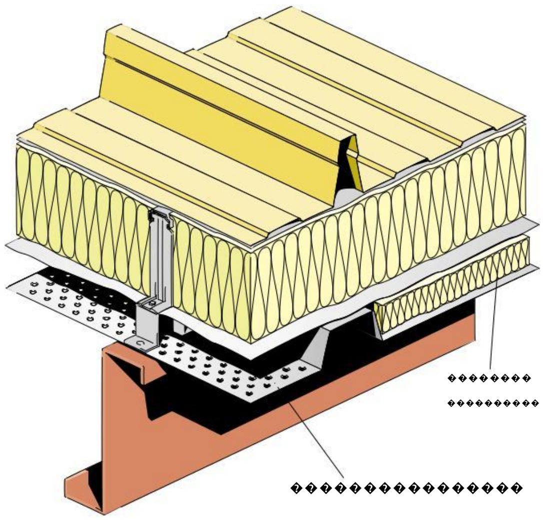

Fig 19: Twin skinned system with sound absorbing liner

7.1 Introduction

The manner in which all elements of building construction perform in the event of a fire is of prime concern to the designer, the occupant, the building owner and the building insurance company. Profiled metal cladding constructions must therefore conform to specific requirements which are defined in the Building Regulations Approved Document B. They may also have to comply with other requirements defined by building insurance organisations, such as the Loss Prevention Council (LPC).

The purpose of the Building Regulations is to ensure the health and safety of people in or about the building. The main requirements are:

- To provide a safe means of escape for the building occupants by preventing internal fire spread.
- To prevent the spread of fire to neighbouring property.
- To prevent an external fire from setting fire to the building.
- To provide access for the Fire Brigade.

Generally metal roof cladding has to limit the spread of fire on its internal liner face, prevent the spread of fire through any cavity, and resist the spread and penetration of fire on its weathersheet side. Roofs do not usually need to provide any period of fire resistance.

European Standard test methods have now been published, and it is now possible to claim compliance with Approved Document B using either the original BS 476 tests or the new European tests.

7.2 Reaction to fire

The Surface Spread of Flame performance of the internal surfaces of cladding sheets is determined by testing to BS476 Part 7, giving classifications of Class 1, 2, 3 & 4. Profiled liner sheets generally achieve Class 1, the best rating. The sheets will also achieve a rating of $I<12$ and $i_1<6$ in the BS476 Part 6 Fire Propagation test. The combination of these two results means that liner sheets can be designated Class O according to the Building Regulations, and their use is unrestricted.

Alternatively, the reaction to fire classification can be determined using the Single Burning Item (SBI) test BS EN 13823 and the classification to BS EN 13501-1. Profiled steel liner with 25 micron polyester coating achieves a classification A1, which is the best classification, and means use of the liners is unrestricted.

7.3 External surface

External surfaces of roof cladding must demonstrate adequate resistance to the spread and penetration of fire from outside. This is tested according to BS476 Part 3 and given classifications of AA, AB etc through to DD. The first letter denotes the rate of penetration through the construction, A being the best. The second letter refers to the spread of flame, and again A is the best. The classification is accompanied by EXT for external, S for sloping or F for flat. Profiled cladding generally achieves the top rating EXT.SAA or EXT.FAA.

There is no equivalent European classification for the external fire performance of roofs in Approved Document B (2003)

7.4 Cavity barriers

The regulations require that the size of all hidden cavities is restricted by cavity barriers to prevent the unseen spread of fire. However, according to B3 10.11g, cavity barriers are not required in double profiled metal skin roof constructions provided the surfaces of the insulation have a surface spread of flame of Class O or 1, or European Class C-s3, d2 or better, and make contact with the inner and outer sheets.

7.5 Building insurance

Typical twin metal skin roof constructions, which are insulated with mineral fibre (glass or rock), are considered to be non-combustible by insurance companies, and do not create any particular hazard in relation to fire. No type approvals, such as LPC, are normally required.

- **Design loading**

Roof cladding systems and their fixings must be strong enough to withstand the worst combinations of wind, snow, imposed and dead loads calculated in accordance with BS6399 – see Fig 20.

Load case (1)	**Load factors** (2)
Dead + imposed	1.4 Wd + 1.6 Wi
Dead + snow drift	1.4 Wd + 1.05 Wsnow
Dead + wind	1.4 Wd + 1.4 Wind
Dead − wind	1.0Wd – 1.4 Wind
Attachment (3)	1.0Wd – 2.0 Wind

Notes:

- Wd = deadload
  Wi = imposed load (BS6399:Part 3)
  Wsnow = snowdrift load (BS6399:Part 3) Wind = wind load (BS6399:Part 2)
- These load factors are mostly from BS5950: Part 5 and are also adopted in BS5427. They apply to the metal profile.
- Attachment refers to the fixing assembly (fasteners or clips). A minimum factor of 2 should be used and may be increased for timber and other non-steel substances.

Fig 20: Load factors

There are two other special load cases for roofs:

- Foot traffic:

For many roof constructions point loading due to foot traffic is one of the critical load cases. The minimum thicknesses specified in section 2 are generally required to enable the roof to withstand foot traffic during assembly, but even these are not immune from damage, if care is not taken. Metal roof cladding is normally only designed for cleaning and maintenance loading. If regular access is required special walkways should be provided. The appearance of some roofs, particularly if made of aluminium, may be impaired by excessive foot traffic.

- Impact loading – Non fragility:

  When people walk on roofs during construction or to carry out maintenance, there is always a risk of falling over, and this can cause an impact load on the roof. For the safety of the individuals, the roof construction must be able to withstand this loading without failure, and be classed as non fragile.

  The non fragility of profiled sheet roof constructions is determined using the method in ACR[M]001:2000. The test involves dropping a 45kg sand bag from 1.2m onto a sample of the construction, built on a special test frame. Provided the bag is retained on the construction, no matter where the bag is dropped, the sample can be classed as non fragile.

  A classification system A, B, C, is used to show how many impacts the sample will withstand and how much damage is caused:

  Class C is one impact, with damage

  Class B is two impacts, with damage

  Class A is two impacts, with no damage

  For the whole of a particular roof to be classed as non fragile, all the various elements, such as roof sheets and rooflights, and the junctions between the elements, must be non fragile. This must include any special details on the roof, such as hips, curves, and varying purlin centres.

  The performance depends on the assembly of components, and not just the sheet material, so details at supports such as fasteners are normally important. Correctly assembled profiled steel outer roof sheets with a thickness of 0.7mm would normally be expected to achieve Class B, either as single skin or as part of a double skin system. Correctly fixed profiled liner can also be classed as non fragile, which can be an advantage during construction and maintenance, but because the material is only typically 0.4mm thick, the construction is much more sensitive to correct fixing details and correct installation. The manufacturers of the individual roofing elements and systems should provide non fragile specifications for their products.

8.2 Load span tables

Profiled metal cladding manufacturers all provide load span tables for their products to enable the building design engineer to select suitable purlin spacings to accommodate the design loadings calculated above. Typically the spacing would be 1.8m, though this may be reduced in valleys or behind parapets where high snowdrift loadings can occur, or at eaves, verges and corners, where there may be high local wind suction loads. Additional fasteners may be required in these areas, to withstand the high suction loads. The normal maximum span for lightly profiled liner sheets is 1.8m.

8.3 Spacer systems

The spacer system must be strong enough to transfer all loads acting on the weathersheet into the building structure, while maintaining the cavity for the insulation. There should not be excessive deflection particularly under foot traffic loads.

The various spacer systems described in section 2 have different fixing arrangements but in all cases there must be sufficient fasteners to resist the loads applied. Wind suction is often the critical load case. Note that pull-out strength of a fastener securing the spacer system depends on the thickness and grade of the purlin to which it is fixed. Thicker material, and higher yield strength give increased pull-out strength.

8.4 Lateral restraint

When fixed correctly, profiled metal roof cladding systems assist in the design of the framework by providing a measure of restraint to the top flange of the purlin. Safe working loads for purlins are based on the assumption that the sheet profile and fastener system employed will provide full lateral restraint.

Experience has shown that 0.4mm steel (or thicker) liner sheets attached at a maximum of

Durability

500mm centres using 5.5mm diameter fasteners generally provide sufficient restraint to light gauge purlins. Some 0.7mm thick aluminium liner profiles of certain alloy grades can give lateral restraint and the manufacturers' guidance should be sought.

Perforated liner sheets used in acoustic absorption constructions may not be strong enough to provide sufficient restraint, depending on metal thickness, profile and the perforation pattern. Each case should be considered carefully.

It is the responsibility of the cladding contractor to ensure that the correct fastener system is used as recommended by the cladding or fastener manufacturer.

9.1 Introduction

Durability is the ability of a building and its parts to perform its required function over a period of time (see BS7543). Virtually all materials will change physically when subjected to UV radiation, moisture and atmospheric pollution, and this will affect their performance. The designer must therefore ensure not only that the materials and details used are suitable initially but also that they will have a satisfactory life, given the necessary maintenance.

9.2 Materials

The materials selected for the roof can have a significant effect on its durability and the amount of maintenance that will be necessary during its life. The components which are exposed to the weather are particularly important.

The type of sheeting material, coating and colour must all be considered. The performance might also depend on the shape and orientation of the building and the environment. Generally, light coloured coatings are preferable because they do not absorb as much sunlight as dark colours, and they are therefore cooler. This means they tend to have the best life and they optimise the thermal performance of the roof.

The table in Fig 21 gives an indication of the life of some coated sheets on a typical 5° roof slope, in an inland, non-polluted environment. The life-in-years shown concern the appearance and the condition of the coating and it can be extended by repainting. The data has been taken from manufacturers' literature and is for general guidance only.

Material	Coating	Life-in-years
Steel	Plastisol - light	23
	Plastisol - dark	10
	Pvf2	15
	Multicoat	20
Aluminium	Pvf2	20
	ARS	15

Fig 21: Expected life of sheets with various coatings

Note that failure to repaint aluminium will not significantly affect the ultimate life of the material.

More detailed information can be obtained from the individual manufacturers.

Rooflights are also subject to gradual deterioration, which will cause fading and embrittlement. PVC is particularly susceptible. These changes can be minimised by careful attention to detail and regular cleaning and discussion should take place with the manufacturer regarding life span. Replacement may be anticipated during the life of the building.

Both plated carbon steel and stainless steel fasteners are available. In most situations involving coated steel cladding, plated steel fasteners provide acceptable performance as long as their heads are protected from the weather. Integral plastic heads are more reliable than push on caps and are preferable. Stainless steel fasteners can be used for improved durability and must be used when fixing aluminium sheets, to prevent bi-metallic corrosion.

The durability of sealants and fillers is also an important issue, for the long term performance of the building. Various grades of these materials are available, and some are more durable than others. They should be specified carefully to ensure their performance will be consistent with the other components in the roof, as most are built into the construction and are very difficult to replace.

9.3 Design details

The materials chosen for the roof must be assembled correctly in order to achieve the maximum durability. Avoiding water and dirt traps by ensuring satisfactory slopes and end laps are particularly important. For maximum durability, all exposed cut edges of steel outer sheets and flashings should be painted immediately after installation.

The life expectancy of materials inside the construction such as spacers, insulation, fasteners, sealants and the reverse side of cladding and liner sheets must also be considered. Provided the building does not have an internal environment with high humidity, and the roof cladding has been constructed correctly with an effective vapour control layer and ventilation (where appropriate), the standard materials and coatings will be satisfactory.

9.4 Maintenance

The coating life shown above, and therefore the durability of the roof, is always dependent on regular maintenance. This will involve inspection, removal of debris, cleaning and repair of any damage found. Gutters are likely to require the most frequent attention because debris tends to collect in them and can restrict their capacity, whilst increasing the potential for corrosion.

Sustainability

10.1 Sustainable construction

Construction and the built environment are fundamental to the health and well being of society, consequently they have been particularly highlighted as sectors where government and legislators would like to achieve significant improvements. Sustainable construction is about achieving a viable balance between economic competitiveness, social benefit and environmental impact. In essence sustainable development has as its goal the following objectives:

- Maintaining high and stable levels of economic growth.
- Achieving social progress.
- Effectively protecting the environment from adverse impact.
- Seeking a prudent use of natural resources (by encouraging recycling and reducing waste).

All of the above factors need to be addressed for construction to become sustainable. As one driver for this, Building Regulations and legislation are requiring that the minimum performance standards are improved, and initiatives like Rethinking Construction are working to drive change throughout the industry.

10.2 Life Cycle Assessment

There is increasing concern about the affect of all buildings on the environment, in terms of:

- Long term global climate change because of carbon based energy use.
- Depletion of earth's non-renewable resources.
- The immediate local impacts caused by, for example, release of toxic chemicals during construction.

To properly evaluate the environmental impact of different design decisions a "cradle to grave" assessment is needed where all of the processes from material extraction, product manufacture, installation, maintenance and finally removal and disposal need to be accounted for. Such assessments are usually referred to as Life Cycle Assessments, and are typically time consuming and onerous to undertake. They are not included directly in Building Regulations at present and there are few direct financial incentives to follow them. However, increasing concern about climate change, the cost benefits in terms of reduced energy consumption, and the use of recycled materials and the risks of companies being sued due to real or perceived health problems affecting employees or the occupants of neighbouring buildings are combining to make these issues increasingly relevant to building designers and owners.

A set of generic life cycle assessments for typical UK constructions has been published in the *Green Guide to Specification* produced by BRE and Oxford Brookes University. This document assesses each building type in terms of its environmental impact on:

- Climate change.
- Fossil fuel depletion.
- Ozone depletion.
- Human toxicity to air and water.
- Acid deposition (i.e. the emission of gasses that contribute to acid rain).
- Ecotoxicity (that is, the emission of substances, usually heavy metals, that impact on neighbouring ecosystems).
- Eutrophication (that is, the production of nitrates and phosphates, which cause excessive algal growth and consequent oxygen depletion in water courses).
- Summer smog.
- Mineral extraction.

Each of these is awarded a grading from A (best) to C (worst) and an overall grade is given to the building type. Industrial metal buildings and roofs achieve overall A ratings and score highly for most of the above impacts. The high sustainability rating of these products reflects the particular advantage of using a comparatively low mass roofing system with less material resource input than other commercial systems.

Generally, metal cladding systems have relatively good sustainability credentials as a result of the opportunities for recycling. Although metal sheeting systems would not be routinely reused at the end of a roof systems life, the material itself can be processed and recycled for other applications. Similarly, the materials used for the manufacture of the metallic components can contain some recycled material. Both of these factors reduce the environmental impact of metal cladding systems, and the growing recycling industry will help to continue to reduce this in future.

Correctly specified metal cladding and roofing systems competently installed should have good thermal performance and achieve a consistently good air tightness standard. This will ensure that the heat loss through the structure will be consistent with that set by the designer, rather than being reliant on the performance of site workers which can often let masonry construction down.

10.3 ISO 14001

Increasingly organisations are adopting ISO 14001 in their management procedures which specifies the actual requirements for an environmental management system. It applies to those environmental aspects which the organisation has control over and this extends to the design, procurement and maintenance of new buildings. As a result, such organisations are requiring that the design team demonstrates and justifies the performance of a proposed development, and where appropriate establish an Environmental Plan to ensure that the impacts of the construction process are minimized. ISO 14001 is applicable to any organisation that wishes to:

- implement, maintain and improve an environmental management system;
- assure itself of its conformance with its own stated environmental policy (those policy commitments of course must be made);
- ensure compliance with environmental laws and regulations;
- seek certification of its environmental management system by an external third party organisation

Awareness of the issues in these documents can help clients meet the increasingly complex demands in a world where environmental concerns are growing in importance.

Construction details and accessories

11.1 Junction details

The typical details shown in this section illustrate the general arrangement at various junctions. In each case, the value and f value associated with thermal bridging are shown. (See section 4). Proprietary systems may have particular requirements and the manufacturers' recommendations should always be followed.

All other junctions and details for a particular construction should be designed adopting the same principles, ensuring continuity of the weatherproofing, vapour/air control layer, and thermal insulation.

11.1.1 Ridge

Provided that the insulation is continued over the ridge to provide continuous coverage, as shown in Fig 22, this will be a minimal thermal bridge.

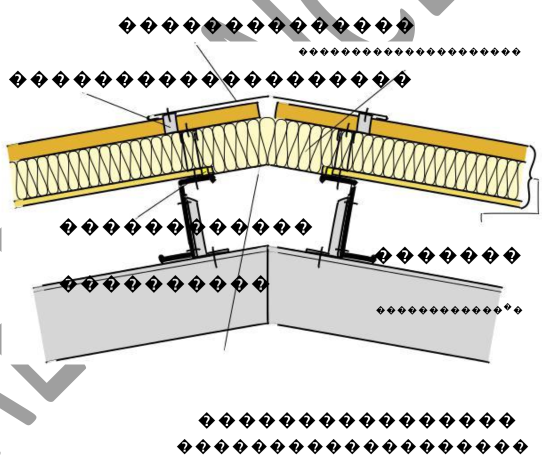

Fig 22: Roof typically f_{min} = 0.91 = 0.01 W/mK

11.1.2 Eaves

The thermal bridge can be minimised by taking the roof liner back to the wall liner, so that it does not cross the wall insulation, and ensuring that any void between the wall and roof insulation is fully filled with insulation as shown in Fig 23.

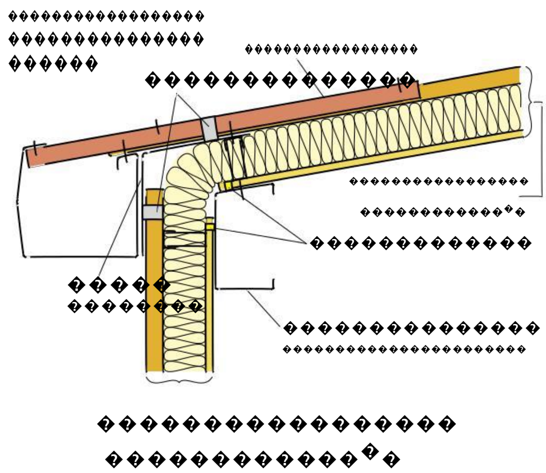

Fig 23: Eaves typically f_{min} = 0.95 = 0.01 W/mK

11.1.3 Verge

The thermal bridge can be minimised by taking the roof liner back to the wall liner, so that it does not cross the wall insulation, and ensuring that any void between the wall and roof insulation is fully filled with insulation as shown in Fig 24.

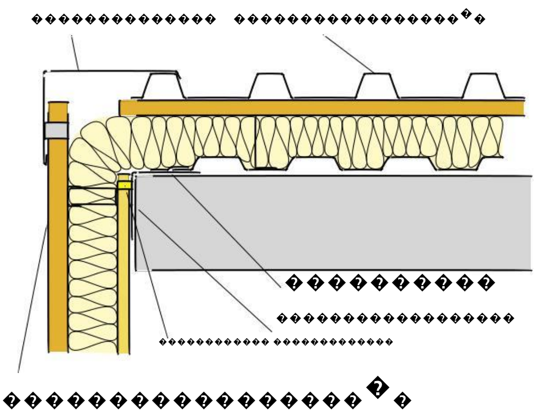

Fig 24: Verge typically f_{min} = 0.95 = 0.02 W/mK

11.1.4. Valley gutter

This detail can cause a very severe thermal bridge if the metal outer layer of the gutter top and roof liner cut across the gutter insulation.

Making the gutter liner more robust and replacing part or all of the gutter outer with a lower conductivity material such as plastic where it cuts across the insulation will reduce the thermal bridge; if the roof liner is stopped short as well so that the insulation layer is continuous, the thermal bridge can be largely eliminated (Fig 25)

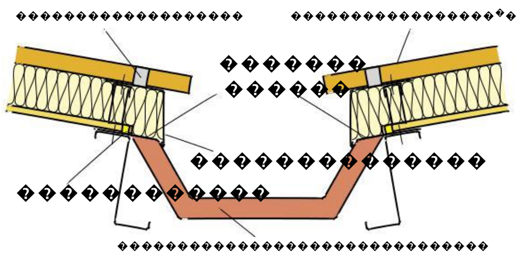

Fig 25: Valley gutter with thermal break across the gutter insulation

Typically f_{min} = 0.95 = 0.17 W/mK

11.2 Rooflights

Rooflights are used in many industrial and commercial buildings. Typically a rooflight area of approximately 10% of the total roof area is used. Great care should be taken in their specification and installation, and the manufacturer's guidance should always be followed. See also MCRMA technical paper No 1 *Recommended good practice for daylighting in metal clad buildings*.

11.3 Roof drainage

The roof drainage system is an important aspect of the overall roof design. This is particularly the case for parapet and valley gutters, which are inside the building line and are effectively part of the roof. Any overflow or leaks into the building would be unacceptable. Eaves gutters are outside the building and their design is less critical.

The roof drainage design is based on BS EN 12056-3:2000, *Gravity drainage systems inside buildings – roof drainage, layout and calculation*. The design process and the correct selection of materials can be complex and it is recommended that the designer consults one of the companies that specialises in the design and manufacture of roof drainage systems.

11.4 Small penetrations

Small diameter penetrations such as flues and other service pipes can be successfully weatherproofed using proprietary or purpose-made sleeving for use with profiled cladding. These should always be positioned at the profile crown as shown in Fig 26 to ensure they do not create a dam across a trough. If this cannot be achieved, an apron flashing should be fitted on top of the profiled sheets upslope to the ridge to prevent ponding behind the penetration, or a site applied GRP flashing could be formed. (See 11.5). The manufacturers' recommendations should always be followed.

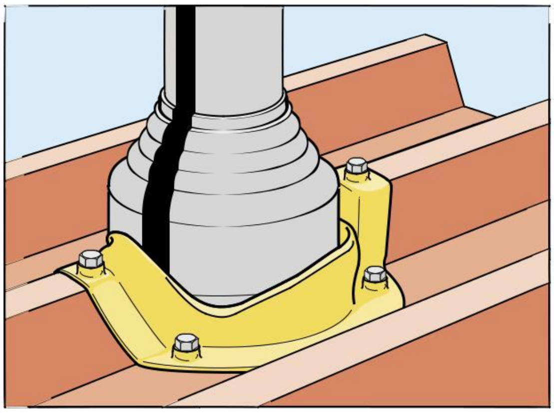

Fig 26: Typical neoprene rubber proprietary pipe flashing

11.5 Large penetrations

Large penetrations such as fans, smoke vents etc. often require additional structural support between purlins. The penetrations should ideally be placed at or close to the ridge where they can be waterproofed more easily. If used downslope, a special soaker sheet has to be used to divert the flow of rainwater around the sides of the penetrations. The accessory must then be fixed and weathered to the upstand.

These soakers are customised to match the weathersheet profile and the size of the penetration. They are typically fabricated from GRP, aluminium or painted galvanised steel. Ideally they should be fitted during cladding when normal end and side lapping details can be used. Retrofitting is also possible but might involve using cover sheets or apron flashings back to the ridge. These can be unreliable, unsightly and expensive.

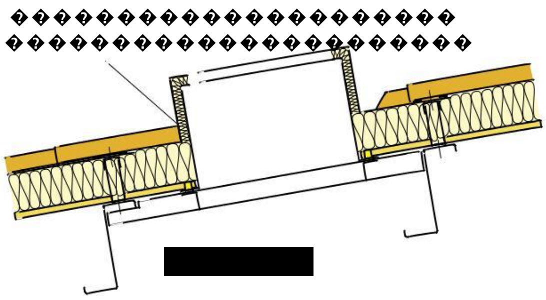

Fig 27: Large penetration

Site applied GRP (or similar liquid applied system) can provide a good solution for all sizes and shapes of penetration. This must be carried out by specialist sub contractors to ensure satisfactory adhesion to the profiled weather sheeting. Contact MCRMA members for further details.

Whenever a penetration is fitted to the roof it is essential that the vapour control layer, insulation and breather membrane (if fitted) are correctly detailed and constructed.

11.6 Flashings

Flashings are normally manufactured in the same material and thickness as the cladding, at least 0.7mm for steel and 0.9mm for aluminium. Where the leg length of a flashing exceeds approximately 200mm, it will be difficult to maintain a flat appearance and it is advisable to introduce a bend or stiffener to straighten and strengthen the material. See examples in section 11.1)

Exposed edges should be stiffened using one of the details shown in Fig 28.

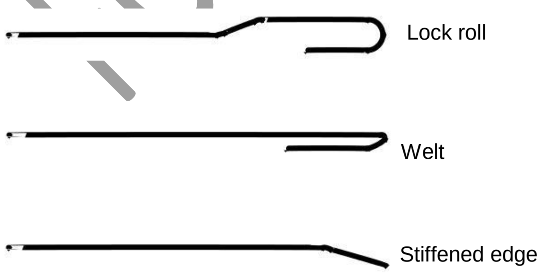

Fig 28

Most flashings used on roofs are 'open' and can be lapped, typically including stitching fasteners at a maximum spacing of 100mm, and sealant on the weatherside of the fasteners. 'Closed' sections, such as some eaves gutters, use butt straps behind the joint. These should be at least 150mm long. For detailed guidance see MCRMA technical paper No. 11 *Flashings for metal roof and wall cladding: design detailing and installation guide*.

Further typical details are available on the MCRMA web site at **www.mcrma.co.uk**

Site work

12.1 General

Metal roof cladding should be fully detailed on cladding drawings for each individual building. The drawings should include all the necessary dimensions, components, fasteners, seals etc. to enable the sheeters to install the cladding in accordance with the designer's requirements, in order to achieve the specified performance.

Responsible supervision and regular inspection is essential to ensure structural integrity, satisfactory performance, acceptable appearance and quality in general.

Deviations in steel frame construction, rafters and purlins etc. can often be greater than those acceptable for the cladding material, especially at critical bearing positions such as end laps, or at junctions.

The steel framework should be surveyed prior to handover to the roofing contractor. Any deviations in line, level and plumb must be acknowledged by all parties and the necessary adjustments made to suit the cladding requirements before starting the installation.

12.2 Transport, handling and storage

Loading and off-loading packs by crane or fork-lift should be carried out with care to avoid damage to the outermost sheets or panels in the pack. Never off-load with chains, use only wide soft slings for lifting. Use lifting beams, if recommended by the manufacturer

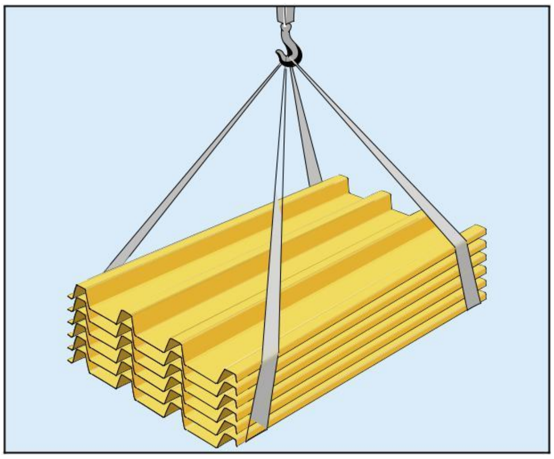

Fig 29: Slings used for lifting

Stacks should be carefully positioned and stored on site to prevent damage or deterioration. Particular attention should be paid to the following points:

- Position away from vehicle and pedestrian routes
- Site on bearers on firm flat ground
- Cover and ventilate
- Ensure labelling is intact

Some sheets and panels are supplied with a protective plastic film on the weatherface to help prevent minor damage to the coating. This must be removed as soon as possible after the cladding has been installed because if it is left in place for long periods the film will become very difficult to remove. Individual manufacturers' instructions should always be followed.

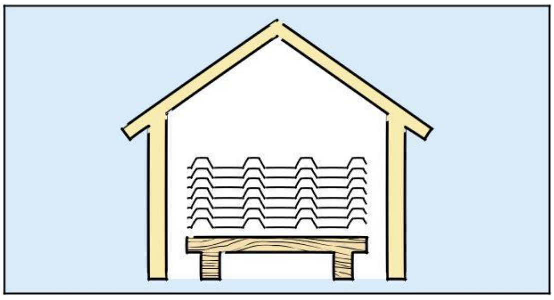

Fig 30: Storage of materials

12.3 Site cutting

Site cutting is generally avoided by the use of sheets cut to length in the factory. However, where site cutting is unavoidable nibblers and reciprocating saws (jig saws) should be used. Abrasive wheel cutters must not be used because they generate heat and will damage the coating. For optimum durability site cut edges, eaves and end laps of steel sheets should be painted.

12.4 Health and safety

As in all building work, good safety standards are essential to prevent accidents. In accordance with the Health and Safety at Work Act and the Construction (Design and Management) or CDM Regulations, the building should now be designed with safety in mind, not only for the construction period itself but also throughout the normal life of the building. This must include considering the safety of people involved in maintenance, repair and even demolition. It might mean providing permanent access to the roof via a fixed ladder and hatch, walkways and parapets, for example.

Construction of the roof is one of the most hazardous operations because of the potential for falls or material dropping onto people below. The contractors must plan and document a safe system of work before starting construction. This would take the fragility of the cladding materials into account, but initially, safety nets are normally used. Whilst fully fixed metal roof sheeting is regarded as non fragile, rooflights and profiled metal liners must be treated with more care. (See section 8.1)

In addition to the basic safe system of working the following specific precautions should be taken when using metal cladding:

- Take care when handling sheets to avoid cuts from the edges of the sheets. Wear gloves to protect hands.
- Take normal precautions when lifting heavy awkward objects to avoid lifting injuries, in accordance with the Manual Handling Operations Regulations.
- When cutting wear goggles and dust masks.

The strength and visibility of some rooflights can deteriorate during the normal life of a building and present a hazard to maintenance workers, particularly if they have not been trained. The rooflights are usually fixed with fasteners with red plastic heads, to highlight their positions.

This sort of information must now be detailed in a safety file prepared by the planning supervisor (using information provided by the designer) and passed on to the client at handover.

If in doubt about safety issues, guidance can be obtained from the construction section of the local Health and Safety Executive.

Inspection and maintenance

Metal roof cladding is designed and manufactured to give many years of reliable service, but to achieve this, a regular inspection and maintenance programme is required.

Roof cladding and gutters should be inspected at regular intervals and any deposits such as leaves, soil or litter must be removed. Any areas of corrosion or damage should be repaired in accordance with the manufacturer's maintenance manual.

Roof traffic should be kept to a minimum and must be restricted to authorised trained personnel only, using appropriate safety measures.

References

- BS EN ISO 6946 : 1997, *Building components and building elements – Thermal resistance and thermal transmittance – Calculation method*.
- CIBSE Guide A3, *Thermal properties of building structures,* CIBSE 1999.
- BS EN ISO 10211-1: 1996, *Thermal bridges in building construction - Heat flows and surface temperatures, Part 1. General calculation methods*.
- BRE Information Paper IP 10/02, *Metal cladding : assessing the thermal performance of built-up systems which use 'Z' spacers*.
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- BRE Report BR443, *Conventions for calculating U-values*, BRE 2002.
- BRE IP 17/01, *Assessing the effect of thermal bridging at junctions and around openings*, BRE August 2001.
- MCRMA technical paper No. 14, *Guidance for the design of metal roofing and cladding to comply with Approved Document L2 : 2001*.
- BS EN ISO 13788:2001, *Hygrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods*.

Liability

Whilst the information contained in this design guide is believed to be correct at the time of going to press, the Metal Cladding and Roofing Manufacturers Association and its member companies cannot be held responsible for any errors or inaccuracies and, in particular, the specification of any application must be checked with the individual manufacturer concerned for a given installation.

The diagrams of typical constructions in this publication are illustrative only.

MCRMA technical papers

No 1 Recommended good practice for daylighting in metal clad buildings
No 2 Curved sheeting manual
No 3 Secret fix roofing design guide
No 4 Fire and external steel-clad walls: guidance notes to the revised Building Regulations, 1992 *(out of print)*
No 5 Metal wall cladding design guide
No 6 Profiled metal roofing design guide
No 7 Fire design of steel sheet clad external walls for building: construction performance standards and design
No 8 Acoustic design guide for metal roof and wall cladding
No 9 Composite roof and wall cladding design guide
No 10 Profiled metal cladding for roofs and walls: guidance notes on revised Building Regulations 1995 parts L and F *(out of print)*
No 11 Flashings for metal roof and wall cladding: design, detailing and installation guide
No 12 Fasteners for metal roof and wall cladding: design, detailing and installation guide
No 13 Composite slabs and beams using steel decking: best practice for design and construction
No 14 Guidance for the design of metal roofing and cladding to comply with Approved Document L2: 2001
No 15 New Applications: composite construction
No 16 Guidance for the effective sealing of end lap details in metal roofing constructions

Other publications

The Complete Package CDROM

Manufacturing tolerances for profiled metal roof and wall cladding

CladSafe latent defects insurance scheme: basic guide

Composite flooring systems: sustainable construction solutions

Please note: Publications can be downloaded from the MCRMA web site at www.mcrma.co.uk

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