Scheme development: Selection of the external roof envelope system for single storey buildings

This document describes the main design considerations in the selection of roofs for single storey buildings and the roof systems which can be used.

Contents

1. Design considerations

There are a number of considerations to be taken into account in the selection of a roofing product or system. In order to fulfil the design criteria of the roof it is crucial to assess whether the materials and system can accommodate the design over long periods of time and whether it suits the location and environmental climate. Cost is a key factor but should be viewed in terms of the whole life of the materials. Other issues such as detailing, maintenance and disposal should also be considered.

The main factors in the selection of roofing products and systems can be summarised as follows:

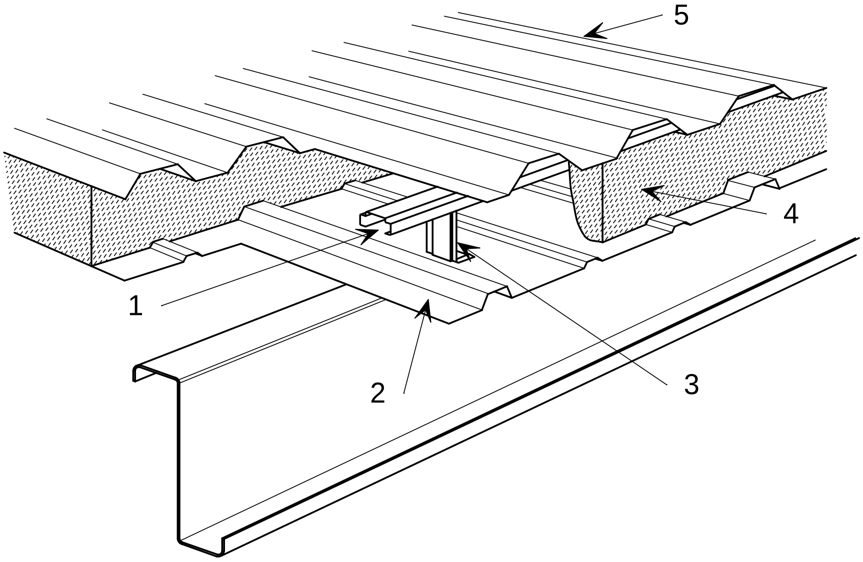
- perform basic function of keeping out the weather
- look aesthetically pleasing
- be available in a range of colours/finishes
- provide for insulation, meeting the requirements of the Energy Performance of Buildings Directive through National Building Regulations
- provide for any fire regulations which tend to be individual to each country
- comply with national requirements for snow, wind and other imposed loads
- provide safe access during the construction phase and future maintenance of the roof structure and in some instances be capable of supporting heavier foot traffic for plant maintenance
- an option to support the load imposed from any additional plant and equipment which may be acting directly on the roof system. Preferably these services should be supported off the main or secondary roof structure
- provide a source of natural day lighting to the internal space
- provide for any acoustic requirements which may include a reduction of noise through the roof structure or control of reverberate noise within the internal space
- become part of a system with weathering and ventilation accessories, and include details for penetration of smoke vents, chimneys, roof lights etc, to give complete integrity
- be a sustainable product, which is manufactured in such a way as to minimise the impact on the environment by reducing CO_2 emissions, conserve resources, increase the use of renewable material, improve productivity, increase recyclability and minimise the impact on-site by reducing the time required, the level of noise, the level of waste and the requirement for the use of water.

There are a number of metal roofing system that are available which can fulfil some or all of these functions; the guide considers a number of low pitched and flat roof options which are specified for a range of building types commonly found in Europe.

2. Profiled sheet roofing systems

2.1 Built-up roof cladding systems

A built up or double skin system consists of metal profiled liner that is fastened to the structure, followed by a bracket and rail spacer system, insulation and the outer weathering sheet (see Figure 2.1). These roofing systems are versatile, offering the designer a number of combinations of colour, profile and texture together with fast economic solutions to meet the thermal, acoustic and fire requirements of the building fabric.



Key

1.	Rail	4	Insulation
2	Liner Tray	5	Sheeting
3	Bracket		

Figure 2.1 Build-up construction using 'rail and bracket' spacers

A modern roof cladding system can be designed to be highly visible, either as a continuation of, or to provide contrast to the walling system. Hidden gutters can be formed behind a low parapet wall or curved eaves can be used to a strong effect allowing a transfer from roof to wall cladding profile.

2.1.2 Internal liners

Internal liners are shallow profiled sheets that require additional support from the secondary steel work. The liner sheet is the first component of the built-up roof to be installed and serves several purposes, including support to the insulation, a vapour tight and airtight seal, and can also be used as a temporary working platform and to provide a weather-tight envelope prior to the installation of the outer sheet. The sheets tend to be supplied in a bright white finish with coating specifically formulated for internal use (see Figure 2.2). Manufacturers will supply other colours to special order.

Figure 2.2 Bright white pressed liner profile have been used on the refurbishment of the roof at Newcastle Station to create the effects of timber planks
(Photograph by kind permission of Corus Profiles & Panels)

Liner sheets are usually cold formed from pre-coated steel with a shallow trapezoidal profile as shown in Figure 2.3. A typical liner panel will have a profile depth between 18 and 35mm with sheet thickness usually either 0,4 mm or 0,7 mm. Providing walk boards etc are used, most sheets will normally have sufficient strength and stiffness to support the weight of cladding operatives or their materials and equipment during the installation of the sheets. The safe working load for the liner should not be exceeded, and manufacturer's recommendations and fixing details should be followed.

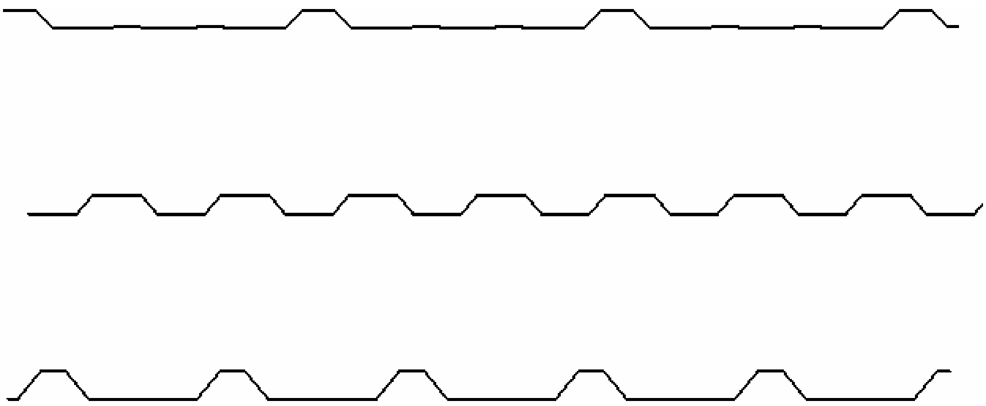
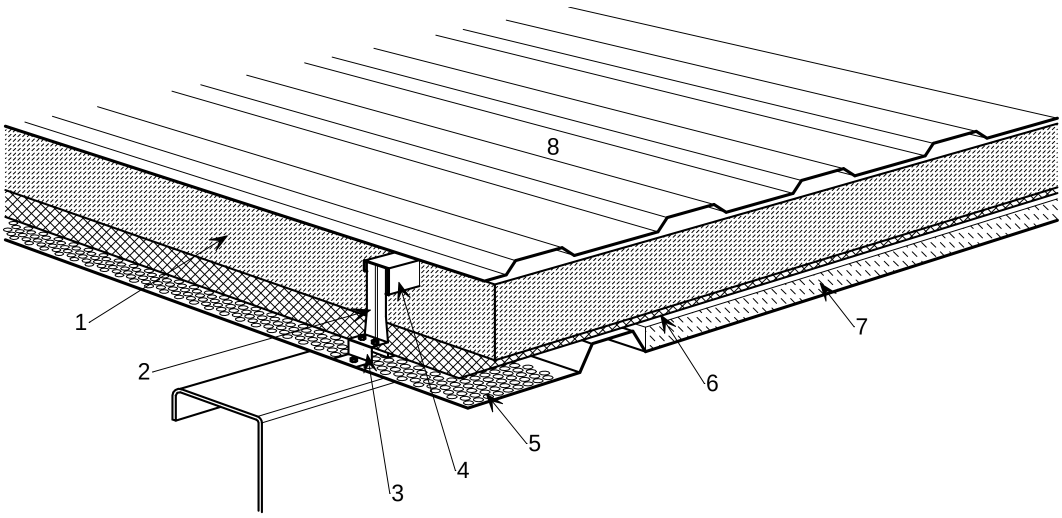


Figure 2.3 Liner profile examples

The sheets must be sealed at both the end and side laps to provide an airtight and vapour tight skin to reduce the energy loss through the roof. Alternatively a polyethylene vapour control layer can be laid and then sealed between the liner and insulation.

The liner profiles shown in Figure 2.3 are designed for use with traditional steel purlins and are, therefore, suitable for spans of approximately 1,5 to 2,0 m (a typical purlin spacing is 1,8 m). Deeper profiles made from thicker steel are available for applications requiring longer spans.

Liner sheets can also be supplied either partially or fully perforated, as part of specialist acoustic roofing systems which are designed to provide sound absorption and reduce the reverberate noise within the internal space. A typical section through an acoustic roof is detailed in Figure 2.4.



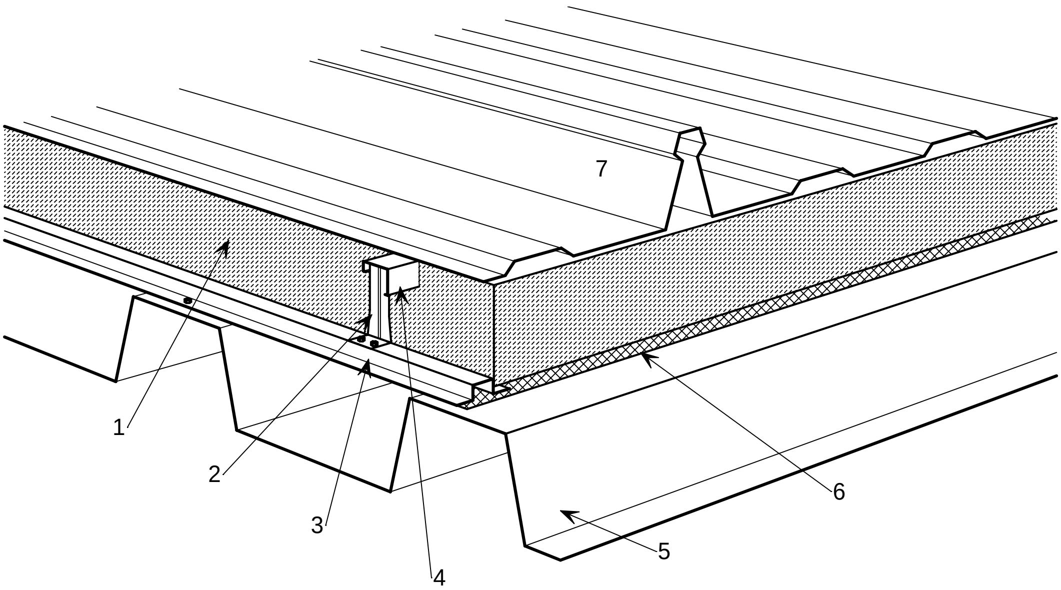
Key

1. Mineral wool
2. Bracket
3. Top hat
4. Rail
5. Perforated lined
6 Vapour control layer
7. Acoustic insulation
8. Profile sheeting

Figure 2.4 Acoustic roofing system with acoustic insulation laid on a perforated liner

2.1.3 Structural support decks

Structural support decks are deep profile sheets that require minimal support from secondary steel work. Used extensively throughout Europe, structural decks provide a clean uncluttered appearance to the soffit of the roofing system. This can bring time savings because the need for secondary steel members to support the roofing system is reduced with additional steel work often only being required around penetrations in the roof, such as roof lights and smoke vents. Structural decks are available in a wide range of profile depths ranging from 150 mm to over 200 mm and material gauges ranging from 0,75 mm to 1,5 mm, enabling solutions for spans up to a maximum of nine metres (see Figure 2.5). The deeper profiles and thicker gauges make these decks suitable to provide a working platform for the cladding installation activities, provided that sufficient protection is provided at edges, penetrations and rooflights.



Key

1. Mineral wool
2. Bracket
3. Top Hat
4. Rail
5. Wide span structural trapezoidal deck
6. Vapour control layer
7. Standing seam sheeting

Figure 2.5 Roofing system on a structural support deck spanning between the main frame reducing the need for secondary steel members

Structural support decks can also be supplied either partially or fully perforated and are used as part of specialist acoustic roofing systems (see Figure 2.6). They are particularly suitable for perforation because of the inherent strength in the profile. Perforating will reduce the spanning capabilities and reference should be made to the manufacturer’s literature.

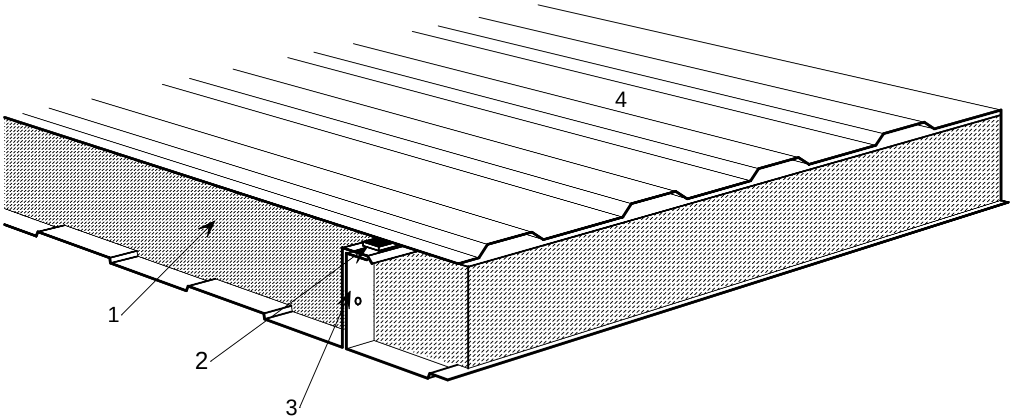
White polyester coated galvanised steel is offered by manufacturers as a standard finish with other colours and finishes available to special order.

Figure 2.6 ***Standing seam roof over a perforated structural support deck with mineral wool insulation to provide sound absorption in a library***
(Photograph by kind permission of Corus P &P)

2.1.4 Structural liner trays

Structural liner trays are cassette linings which interlock and provide a virtually flat finish to the underside of the roof. The trays are structural, generally limited to 6 metres, and require minimal support from secondary steel work. The liner trays usually run from ridge to eaves ideally in one length and are supported by purlins or similar secondary structure at 1,8 m to 4 m. Mineral wool is normally placed between within the troughs of the liner tray and restrained by the tray flanges. A thin layer of insulation or timber battens are placed over the ribs of the tray to reduce the thermal bridge between the flange and the weathering sheet (see Figure 2.7). Vertically running metal profiled outer sheets are then fixed through the thin insulation or battens to the ribs of the tray which provide the structural support for the outer weathering sheet.

Structural liner trays can be designed to act as support for traditional slated or tiled roofs. The trays can replace the need for timber trussed rafters and are ideally suited to steel frame construction. The trays also provide immediate weatherproofing, providing significant cost savings and allow fast track construction. The result is a traditional outward appearance of a tiled roof and a clean internal finish interrupted only by the main roof frames. Structural liner trays can also be supplied either partially or fully perforated and are used as part of specialist acoustic roofing system



Key

1. Mineral wool roll insulation
2. Isolating strip
3. Interlocking joint
4. Profile sheeting

Figure 2.7 Roofing system using a structural liners tray giving a virtually flat finish to the under side of the roof

2.1.5 Insulation and spacer system

The majority of site-assembled built up cladding systems use glass or rock fibre insulation quilts supplied in rolls. Mineral fibre quilt is light weight, has a low thermal conductivity, is easy to handle and has a relatively low cost. A spacer system consists of a bracket support and a rail which provides structural support to the weather sheet as well as creating a cavity for the insulation. The bracket and rail systems are always positioned over and fixed securely to the purlins or other structural members

To cater for the increased thickness of insulation required in modern systems, a new generation of bar (or rail) and bracket spacer systems has been developed. These systems consist of cold formed steel rails, which provide continuous support to the weather sheet, supported at intervals by steel brackets firmly attached to the purlins. Many rail and bracket systems also incorporate plastic pads, which act as thermal breaks, in order to minimise thermal bridging. Typical spacer systems are shown in Figure 2.8

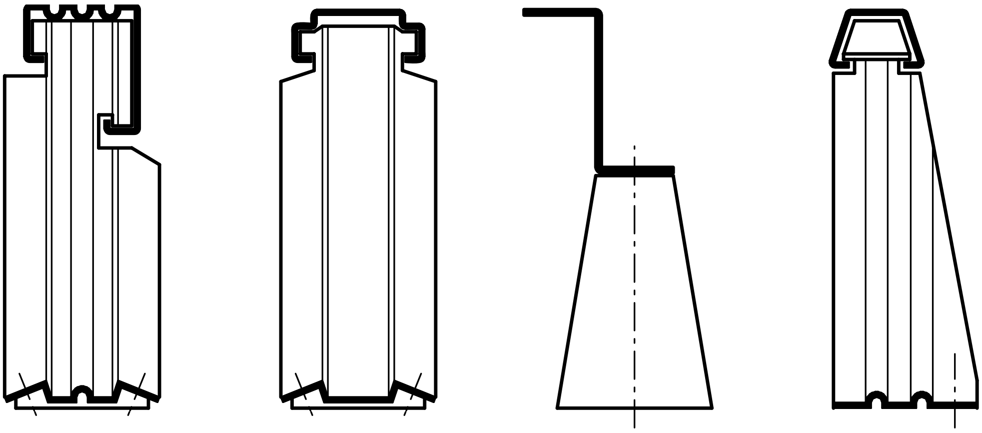
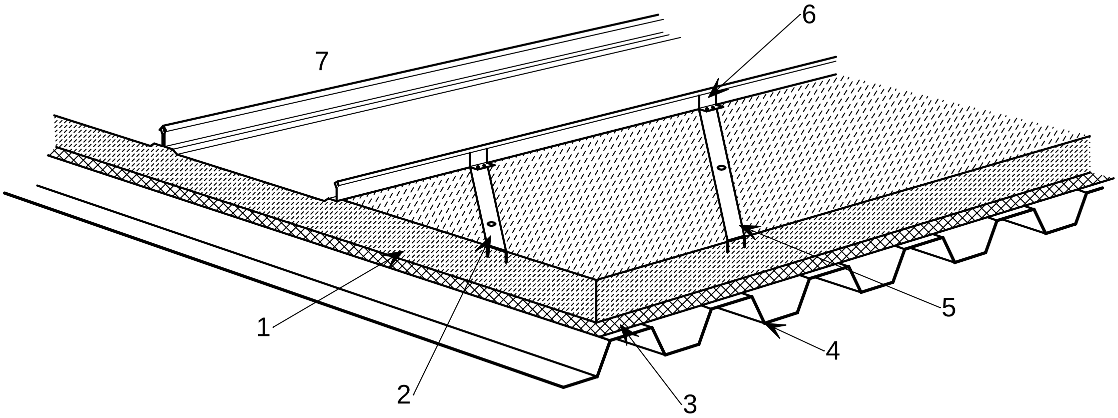


Figure 2.8 Typical Spacer Systems

Alternative systems are available which use rigid mineral fibre or foam insulation slabs. Fixing rails are embedded into pre-cut slots on the face of the insulation. Fasteners are then used to fix through the rails and the insulation into a structural deck which provides full support to the system. The weathering sheet is then attached to the rails. Typical details are shown in Figure 2.9. A feature of these systems is that thermal bridging is almost eliminated because the insulation is only penetrated by a minimum number of screw fixings for a given level of thermal insulation. The thickness of the insulation layer will be less than the equivalent thickness of mineral fibre quilt. A mineral wool slab will provide high sound reduction levels and reduce vibrations through the structure caused by rain noise. The rigid insulation provides good support to the weathering sheet, allowing high accessibility during installation and maintenance.



Key

1. Load bearing insulation
2. Stainless steel fixing
3. Vapour control layer
4. Structural trapezoidal decking
5. Fixing rail
6. Secret fix clip
7. Standing seam insulation

Figure 2.9 Rigid-insulation roofing system which can be designed to provide support to the weathering sheet allowing high accessibility during installation and maintenance

2.1.6 External weather sheeting

General

The primary function of the external weathering sheet is to protect the building from the exterior climate by forming a weathertight envelope. However, the weather sheet should also be regarded as a structural element, as it plays a crucial role in transferring externally applied load (i.e. from wind and snow) through to the other cladding components, secondary steelwork and primary load-bearing frame.

Steel weather sheets are usually manufactured from pre-coated steel coil. The coating is made up of a series of layers comprising a metallic coating (i.e. galvanising), pre-treatment, primer and top/backing coat. The choice of topcoat will depend on aesthetic requirements and the nature of the environment. The following materials are generally used:

Plastisols are thick film coatings typically between 100 and 200 μm. The thermoplastic coating means that they can be embossed with a textured pattern to improve appearance and the relative thickness makes them less susceptible to abrasion and damage.

Polyesters and polyurethanes have similar properties and are based on low cost thin film coatings. These offer limited flexibility and moderate durability and tend to be used for basic external wall applications in drier environments such as those found in Southern Europe. Polyesters provide an ideal reverse side and interior coating as the requirements are generally not as severe as the exterior side.

PVDF (often referred to as PVF_2) is a high grade polymer coating with an inherent UV resistance offering good colour retention and stability. The coating has a good resistance to chalking and gloss reduction. The thin coat finish has limited flexibility and is less robust than other topcoats.

The reverse side of the pre-coated steel is coated with an organic coating with thickness of 5μm and is compatible with most adhesives and paints.

The range of colours offered in pre-coated steel is very wide, from neutral greys through to attractive pastel colours and on to strong primaries. Metal or pearly aspects are possible for some colours and coatings. The choice of colour can determine whether the building blends with its surroundings or stands out in contrast as illustrated in Figure 2.10.

Figure 2.10 ***Build-up roofing system with internal gutters hidden behind the parapet wall***
(Photograph by kind permission of Corus Colors)

Profile

The overall visual appearance is achieved as the result of the basic design, colour and the profile chosen. Shadow can have a marked effect on the overall colour. This shadow effect varies with the profile. With sinusoidal profiles there is a soft effect due to gradual transition from shadow to highlight. With trapezoidal sections the shadows are sharply defined giving character to the cladding.

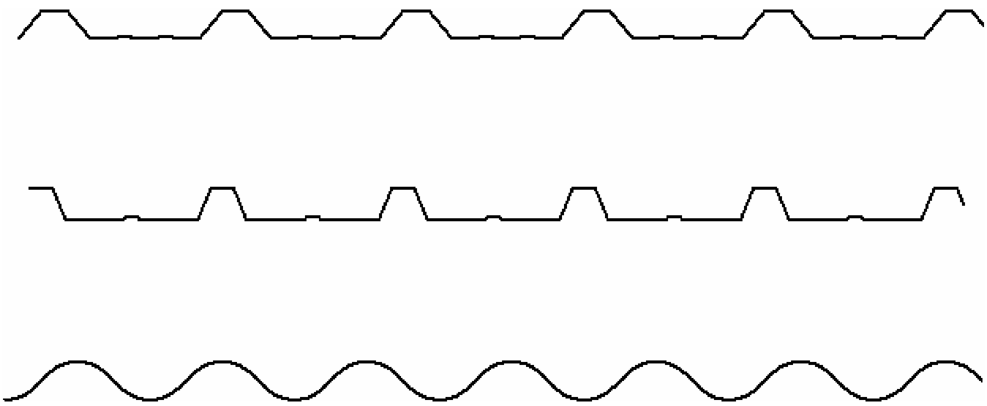


Figure 2.11 ***Weather sheet profile examples***

In order to carry the applied loading from the wind or snow without excessive deflections, it is necessary for the weather sheet to possess an adequate bending stiffness. This is achieved by rolling a profile into the sheet, either trapezoidal or sinusoidal, as shown in Figure 2.11. The depth and pitch of the profile will vary depending on the cladding product, but 32 mm is a typical depth for weather sheets. The profile must be strong enough for the loads and be deep enough to provide adequate run off for the expected rain fall.

In general, roofs are at greater risk of leakage than walls, and this risk increases as the roof pitch decreases. This is an important factor in the design of modern industrial and commercial buildings, since many have low pitch or flat roofs in order to minimise the volume of empty roof space to be heated. Not all types of roof cladding are suitable for use on low pitch roofs. Trapezoidal metal roof sheets with through fix fasteners are generally suitable for roof slopes of 5º or steeper.

2.1.7 Standing seam or secret fix sheeting

For shallower pitches down to 1º, a secret fix system with no exposed through fasteners, special side laps and preferably no end laps should be used.

Standing seam or secret fix sheeting has concealed fixings and can be fixed in lengths of up to 30 m. The advantages are that there are no penetrations directly through the sheeting that could lead to water leakage, and fixing is rapid. Consequently, standing seam systems may be used on very low roof slopes. The fastenings are in the form of clips or halters that hold the sheeting down but allow it to move longitudinally. The disadvantage is that significantly less restraint is provided to the purlins than with a conventionally fixed system and the systems are often used in conjunction with a structural support deck. Typical standing seam sheeting is shown in Figure 2.12.

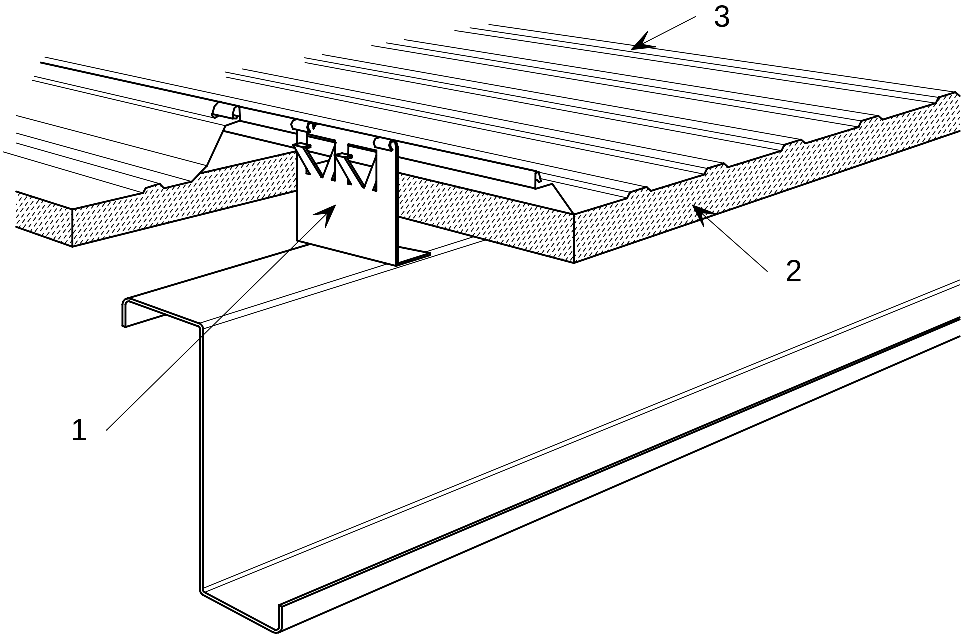
Figure 2.12 Standing seam or secret fix sheeting
(Photograph by kind permission of Wilkinson Eyre Architects. Photographer Morley von Sternberg)

Standing seam systems may also be used on steeper roofs where increased reliability is desired. The profile also has a high aesthetic appeal and the systems are commonly used on hospitals, schools and residential developments providing a strong feature to the overall design. Standing seam roofs can also be laid on a shallow radius to form a curved roof (see Figure 2.13).

Figure 2.13 A curved roof using a standing seam system
(Photograph by kind permission of Wilkinson Eyre Architects)

2.2 Composite panel system

A composite panel consists of an outer sheet and liner sheet which is bonded to a rigid polyurethane (PUR) or polyisocyanurate (PIR) foam in an automated process (see Figure 2.14). The foam cored panels with a typical density of 45 kg/m^3 are light, yet at the same time highly rigid, allowing greater distances between supports.



Key

1. Standing seam clip
2 Insulation
3. Sheeting

Figure 2.14 Composite roof panel with clip system

Composite roof panels can be supplied with a beaded, trapezoidal or corrugated profile with a similar aesthetic appearance to built up and standing seam roof systems. The panels can also be designed to provide structural support for traditional slated or tiled roofs. Composite roof panels tend to be finished with the same coating as those used for built-up systems.

Roof panels are supplied in standard widths, with the length manufactured to suit, allowing rapid mounting on site. The shear resistant bond between the facings and core reduces the need for purlins; this can further be reduced by the selection of structural profiles for the facings.

The manufacturers of composite roof panels offer a range of male and female jointing systems depending on the application and required finish. In addition to remaining watertight, jointing systems must be designed to minimise thermal bridging and maximise the air tightness. Most jointing details will therefore incorporate factory fitted soft joint-sealing strips to ensure a good joint along the length of the panel. Typical joint details are shown in Figure 2.15.

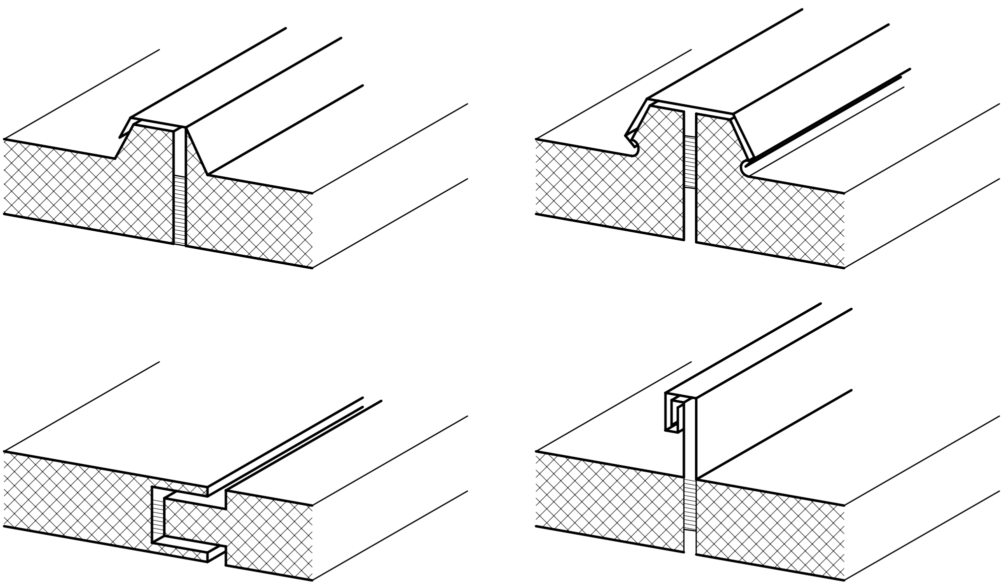


Figure 2.15 Typical composite roof panels joint details

However, most systems are designed so that the end joints are assembled on site. In the end joints the outer profiled skin overlaps the lower element by 100 to 300 mm depending on the system. It is important that the two cut foamed surfaces are joined together, and additional sealing strips are applied to maintain the insulation layer and provide an air tight and weather tight seal.

When selecting a panel system consideration should be given to the tolerance of the frame specified by the manufacturer which will have a marked effect on the finish and performance of the jointing details.

3. Membrane roof systems

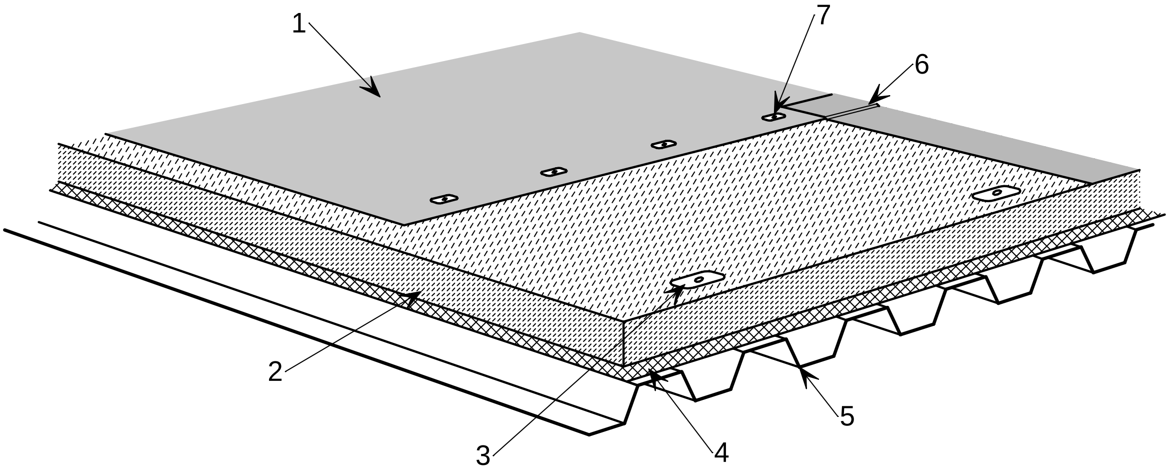
3.1 Design principles

A membrane roof system uses a separate continuous membrane to ensure water tightness. The membrane may be external to the system i.e. a warm roof, or below the insulation layer i.e. inverted roof. A membrane roof system comprises a roof decking that provides continuous support, a vapour control layer or sealed liner, then insulation and a waterproof membrane covering. As well as providing a waterproofing layer, the roofing system must fulfil an aesthetic function, carry maintenance foot traffic and, if required, carry the weight of any dead loads on the roof which may include plant and other service equipment. Preferably these services should be supported off the main or secondary roof structure.

Membrane roof systems are generally divided into generic types which include warm roof, the inverted roof, cold roof, roof garden and roof systems which combine the features of two or more of the roof types. The most popular is the warm roof which is used extensively with steel decking on single storey buildings. Roof gardens are also used, but tend to be on the smaller roofs were a high aesthetic appeal is required.

3.1.1 The warm roof

The insulation is placed immediately below the roof resulting in the structural deck and support being at a temperature close to that of the interior of the building (see Figure 3.1). In a warm roof a vapour control layer is placed on the underside of the insulation to reduce the risk of condensation occurring within the system and condensing on the underside of the membrane.



Key

1.	Single ply membrane	4.	Vapour control layer	7.	Mechanical fixing
2.	Load bearing insulation	5.	Structural roof decking		
3	Mechanical fixing	6.	Overlap		

Figure 3.1 Warm roof system using a mechanical fixed single ply membrane

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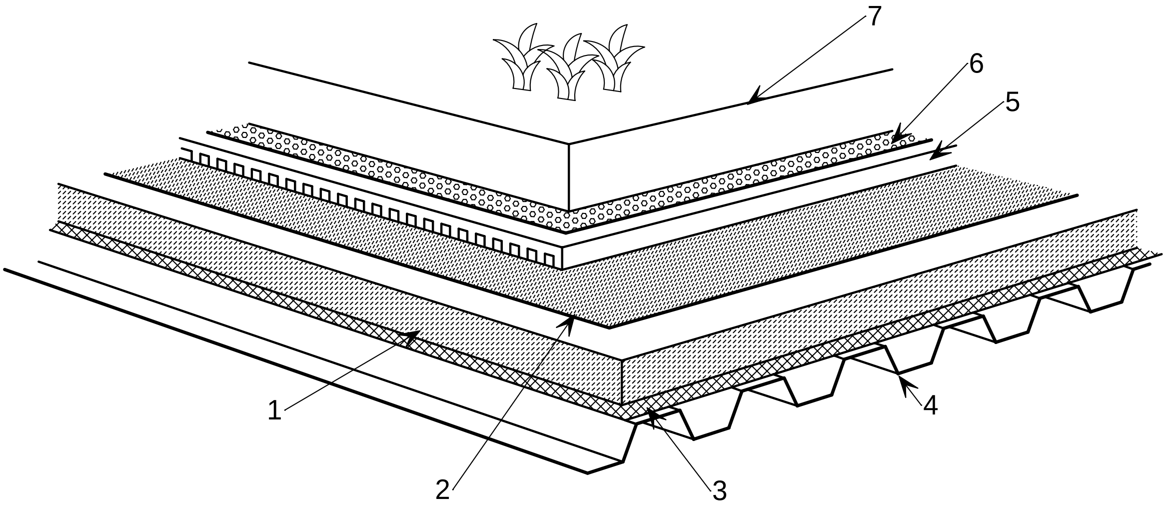
3.1.2 Roof gardens

Roof gardens or green roofs typically comprise either a warm deck or inverted roof construction, with the drainage reservoir, filter and growing medium layers placed above, as illustrated on Figure 3.2 below.



Key

1. Load bearing insulation
2. Build up felt membrane
3. Vapour control layer
4. Structural roof decking
5. Drain
6. Filter layer
7. Growing medium

Figure 3.2 Warm roof system incorporating a roof garden

3.2 Roof decking

Roof decking is the common term used to describe structural metal decking when used with a membrane system. The decking consists of profiled sheets of cold formed galvanised steel. There is a wide range of metal profiles and thicknesses for various load-span relationships. A sheet will have a profile depth between 30 and 100 mm with minimum sheet thickness of 0,7 mm. Stiffeners may be incorporated in the flanges of the webs to improve the efficiency of the profile. These profiles tend to be designed for use with secondary steel and are suitable for spans of approximately 1,5 to 4,0 m.

Many manufactures supply deeper profiles and thicker decks to provide much larger spans. Wide span decks provide a clean uncluttered appearance to the soffit and can bring time savings because the need for secondary steel to support the roofing system is reduced (see Figure 3.3). These decks tend to have a deep profile ranging from 150 mm to over 200 mm deep and material gauges ranging from 0,75 mm to 1,5 mm, enabling solutions for spans up to a maximum of nine metres. Manufacturer's advice should be sought regarding the load-span relationship of their profiles.

Roofing decking will have sufficient strength and stiffness to support the weight of roof contractor operatives and their materials and equipment during the installation of the roofing system. Metal decking may mark if subjected to extreme point or impact load. Where the sheet is required as an exposed soffit, thicker sheet should be considered if localised marking is unacceptable.

Figure 3.3 ***Roof decking with a deep profile fixed between the main frame work with minimal support from secondary steel work.***
(Photograph by kind permission of Wilkinson Eyre Architects. Photographer Paul Rapson)

The normal finish is hot dip galvanised but can be supplied in a coloured finish. Galvanised sheets offer good corrosion resistance at scratches or at holes and cut edges because of the sacrificial action of the zinc. A variety of colour coatings can be factory applied.

Roof decking can also be supplied either partially or fully perforated and be used as part of a specialist acoustic roofing systems which incorporate multi layers of mineral wool or a combination of mineral wool and foam insulation. The insulation can be cut to fit in the profiles or laid as a continuous layer across the ridges of the deck.

3.3 Insulation

The main function of thermal insulation is to provide a resistance to heat flow by either trapped air or gas. An insulation board should not only be chosen for its thermal efficiency but also for its ability to provide a firm support for the waterproofing, be handled and fixed without damage, and have a robust working surfaces that are easy to cut without damage to product. The type, properties and thickness of the insulation will also be determined by the width of the troughs of the profiles. The products can be generically in terms of their behaviour into two groups.

- **Cellular materials,** which derive their performance from the thermal resistance of air or gas trapped within a cellular structure and from the thermal resistance of the cell walls. Insulation materials include ridgd urethane foam either Polyurethane (PUR) and Polyiscocyanurate (PIR), Phenolic foam (PF), polystyrene – expanded (EPS), Polystyrene – extruded (XPS) and Cellular glass (CG).
- **Fibrous materials,** which derive their performance from air trapped between fibres laid perpendicular to the direction of the heat flow. Insulation materials include Mineral wool (MW), Perlite (EP) and Granulated cork (C).

Wide ranges of insulation boards are available which incorporate refinements to the basic material. Some are manufactured with facings of paper, metal foil, glass fibre tissue or bituminous primer. Composites can be manufactured with an overlay factory-bonded to it. Composites combine the thermal performance advantages of cellar or fibrous insulation with the load-resistant and/or fire-resistant properties of a dense overlay.

Flat roof composite PIR panels are also used to provide support to the waterproof membrane. These panels tend to have a deep deck profile for structural support and an unprofiled steel topsheet. A single ply bituminous, PVC or EPDM membrane is either fully bonded or mechanically fixed to the top sheet.

3.4 Membranes

There are many different formulations for roofing membranes both for the waterproof and vapour control layer. Several generic types have emerged.

3.4.1 Built up high performance membrane systems

Built up membranes are formed on site from two or more layers of bituminous felt. A higher performance specification will have a polyester fibre base and be coated with oxidised or modified bitumen. The felts can be applied by either ‘pour and roll’ in which liquid bitumen is used to bond the water proof membrane, felt vapour control layer and insulation layers or ‘torch applied’ in which the membranes are bonded by a blow torch or other heat source (see Figure 3.4 below) or with a self adhesive backing. The insulation is either bonded or mechanically fixed.

Figure 3.4 A built up bituminous membrane being sealed by hot air welding
(Photograph by kind permission of Ruberoid)

3.4.2 Single ply membrane system

Single ply membranes are typically a polymeric membrane that is applied in a single layer. The characteristics of the membrane and application method can be varied depending on the formulation, the reinforcement/carrier and product process. There are several commonly employed methods of application.

One method uses mechanical fastening, in which screw fasteners and either a washer and or bar are used to secure both the membrane and insulation. This system is particularly suited to application on a metal decking because the membrane, insulation and vapour control layer can be applied rapidly and the roof is made water tight in a single application (see Figure 3.5).

A second method is to use an adhesively bonded system using a proprietary adhesive that can be either fully, partially bonded depending on the manufacturer.

A third method is 'loose laid' whereby the membrane is loosely laid on the substrate and is restrained by the weight of either round wash ballast, paving slabs or soil and planting (commonly know as a green roof).

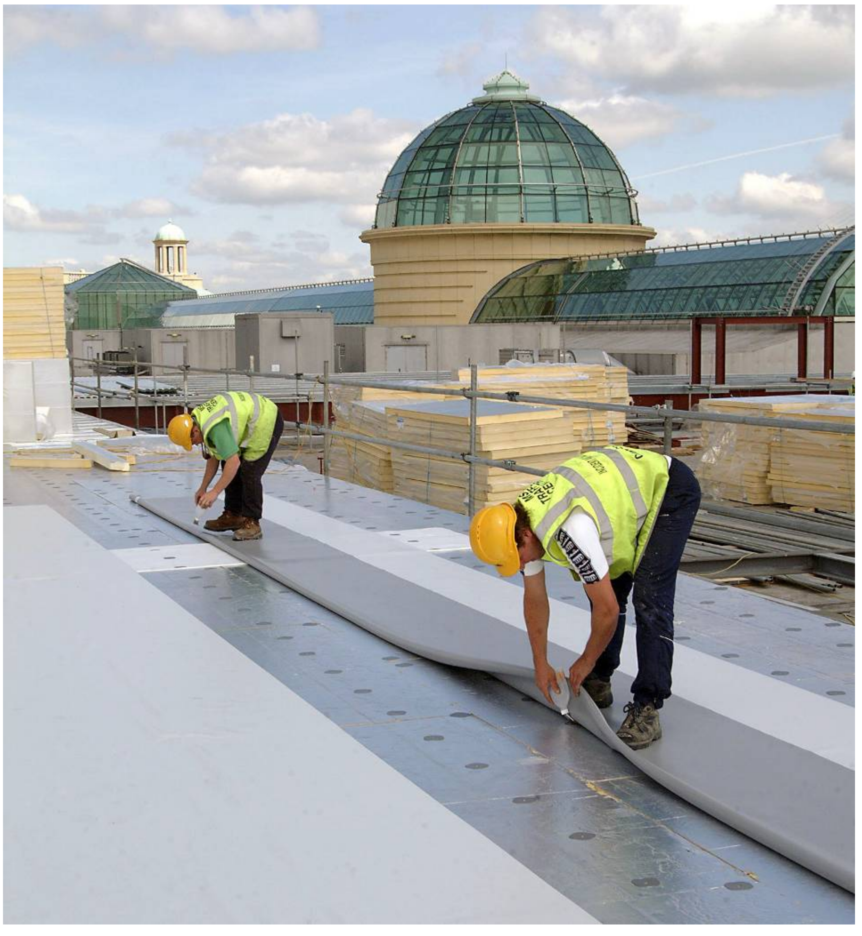


Figure 3.5 ***Warm roof construction using a single ply membrane which is fused to the head of the mechanical fixing***
(Photograph by kind permission of Sika-Trocal UK)

3.4.3 Liquid applied membranes

Historically the most common form of liquid membrane was mastic asphalt. Mastic asphalt is composed of suitably graded limestone aggregate bonded together with bitumen or modified bitumen to make a dense membrane with no voids. Mastic asphalt is used for roof waterproofing, bridge-deck waterproofing and for wear courses above waterproofing on decks subject to traffic (see Figure 3.6). The properties of mastic asphalt have been enhanced by the addition of polymers which improve the elastic properties of the membrane. Mastic asphalt must always be laid over a deck which remains ridged and is detailed to overcome expansion and contraction to avoid cracking of the membrane.

A number of liquid applied polymeric membranes have been formulated; these are often used on refurbishment projects over existing roofing systems to prolong the life of the roof.

Figure 3.6 ***Mastic asphalt be laid over a sheathing felt and glass tissue faced polyurethane boards which were first bonded in hot bitumen onto a felt vapour control layer***
(Photograph by kind permission of Permanite Asphalte)

4. References

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