STEEL BUILDINGS IN EUROPE

Single-Storey Steel Buildings
Part 8: Building Envelope

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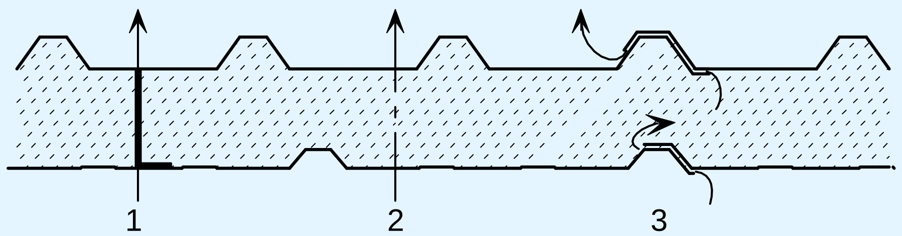
emissions and meeting this obligation will require significant changes in many sectors of industry, especially construction.

A significant proportion of carbon dioxide emissions in Europe is related to the operational energy requirements of buildings (heating, lighting, ventilation etc.). This issue is addressed by European Directive 2002/91/EC: *Energy performance of buildings*[7]. Although many factors influence a building's energy efficiency, the thermal performance of the building envelope is significant. Consequently, it has been sought to reduce energy consumption by improving the thermal performance of the cladding and associated components.

The main sources of heat loss through the building envelope are shown in Figure 3.2.



1 Thermal bridge (metal spacer)
2 Thermal transmittance through insulation
3 Air leakage through joints

Figure 3.2 Main sources of heat loss through the building envelope

3.3.2 Thermal transmittance

Thermal transmittance through the building envelope can be a significant source of energy loss within a building, especially if there is insufficient insulation. One measure of thermal transmittance is the "U-value", which is defined as the rate of heat transfer through an element of the building envelope (e.g. a wall, window, section of roof or rooflight) per square metre. The SI unit for the U-value is W/m^2K. For an individual component such as a cladding panel, the elemental U-value depends on the conductivity and thickness of the insulation, the profile shape and the presence of thermal bridges. Cladding and insulation manufacturers usually quote U-value for their products for a range of insulation thicknesses. Alternatively, the U-value of a given built-up of envelope may be calculated using software.

National regulations generally specify maximum U-values. These are often the weighted average (or similar "overall" figure) for the whole of the roof or wall, with maximum values for individual elements such as doors. The individual elements tend to have much higher U-values than the cladding.

Typical limiting U-values are shown in Table 3.1.

Table 3.1 Limiting U-values

Element	Area weighted average ($Wm^{-2}K^{-1}$)
Wall	0,35
Roof	0,25
Window	2,2
Pedestrian door	2,2
Roof ventilator	6

Over recent years, the drive to improve the energy performance of buildings has resulted in a significant reduction in the U-values for building envelope elements, resulting in a considerable increase in insulation thickness. This has had important implications for the structural performance of the cladding system and its relationship with other structural elements. Of particular concern to the structural engineer are the increased depth and weight of the cladding and its ability to adequately restrain the purlins or side rails. Inevitably the trend will continue towards improved thermal efficiency. However, the diminishing returns obtained from further reductions in U-values means that in future more emphasis is likely to be placed on airtightness and the performance of mechanical services, rather than ever increasing insulation thicknesses.

While some countries have adopted the U-value as the preferred means of quantifying the performance of the envelope, elsewhere the chosen parameter is the R-value or thermal resistance. The R-value is simply the reciprocal of the U-value and the points noted in the preceding paragraphs are equally applicable in these countries.

Typical U-values for different cladding systems are shown in Table 3.2.

Table 3.2 Typical U-values for cladding

Element	U-value ($Wm^{-2}K^{-1}$)
Built-up system, 180 mm insulation	0,25
Built-up system, 210 mm insulation	0,2
Composite panel, mineral fibre, 120 mm	0,34
Composite panel, mineral fibre, 150 mm	0,27
Composite panel, PIR, 60 mm	0,33
Composite panel, PIR, 100 mm	0,20

3.3.3 Thermal bridges

Thermal bridges are areas or components within the roof or wall cladding assembly whose thermal insulation properties are lower (often much lower) than those of the surrounding material, thereby permitting local high heat flows through the building envelope. A common example of a thermal bridge would be an all-metal spacer in a built-up cladding system. In general, all metal components will act as thermal bridges, because of their high thermal conductivity, unless specific measures are taken to interrupt the heat flow by introducing a layer of thermal insulation. Thermal bridging increases the heat loss from a building, thereby increasing the operational energy requirement. It can also lead to a reduction in the internal surface temperature of the cladding, causing condensation to form under certain conditions.

3.3.4 Airtightness

The airtightness of a building is central to the requirements of the building regulations and is likely to become even more important as architects strive to improve the thermal performance of the building envelope without significant increases in insulation thickness. The airtightness of a building is quantified in terms of its air permeability, which is defined as the volume flow rate of air per square metre of building envelope and floor area at a given pressure. The maximum permissible air permeability for a given building will depend on a number of factors including the requirements of the building regulations, the specified CO_2 rating for the building and the means by which this rating is to be achieved (e.g. the architect may specify a very low level of air permeability as an alternative to increasing the thickness of insulation). In many countries, achievement of the specified air permeability must be demonstrated by post-construction testing.

3.4 Interstitial condensation

Interstitial condensation occurs within the layers of the cladding construction and is due to warm moist air from within the building penetrating the liner and condensing on the cold outer sheet and other components. The severity of the problem will depend on the relative humidity of the air within the building, the external air temperature and humidity, and on how well the liner is sealed. Buildings in cold climates and those containing swimming pools, laundries or other similar applications are most at risk, as are cladding systems that incorporate a perforated liner and separate vapour control barrier. In extreme cases, the condensation could result in corrosion of steel components within the roof assembly or in wetting of the insulation.

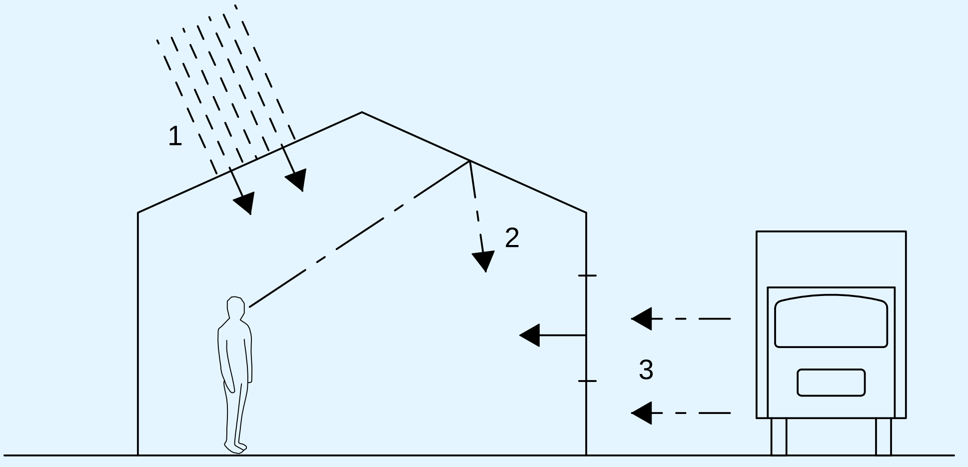
Recommendations for avoiding interstitial condensation are usually given in National Standards.

3.5 Acoustics

Depending on the application, acoustic performance can be an important consideration when specifying roof and wall cladding. There are three categories of acoustic performance to consider, as illustrated in Figure 3.3.

3.5.1 Airborne sound transmission

Where there is a need to limit the passage of sound through the building envelope, the cladding specifier needs to consider the Sound Reduction Index (SRI) of the cladding. The SRI is a measure of the reduction in sound energy (in decibels) as sound passes through a construction at a given frequency. The acoustic performance of a particular cladding system will depend on the insulation material, the weather sheet and liner sheet profiles and the method of assembly. Of these, the insulation is the dominant factor, with soft mineral wool insulation giving better sound insulation than rigid board (dependent upon density).



1 Impact noise from rain
2 Reverberation
3 Airborne sound transmission

Figure 3.3 Categories of acoustic performance

3.5.2 Reverberation

In certain applications, such as offices or residential accommodation, internal acoustic performance might be critical to the functionality of the building. Of particular interest is the reverberation caused by sound waves reflecting off hard internal surfaces, including elements of the building envelope. Typically, the internal finishes of the building will be used to limit reverberation, but architects may also take advantage of the sound absorbing properties of the cladding insulation layer by replacing the standard liner sheet with a perforated liner. Where the envelope consists of insulated sandwich panels, it is not uncommon to install a perforated liner and a layer of mineral wool insulation on the inside of the envelope in order to reduce reverberation.

3.5.3 Impact noise

The noise created by the impact of rain or hail on metal roof sheeting can sometimes create a nuisance for the building occupants. Where impact noise is considered to be important, it can sometimes be reduced by placing a flexible insulation layer directly below the outer sheet to act as a damper.

3.5.4 Noise associated with building services equipment

Consideration should also be given to attenuating noise emanating from services equipment. These include providing sound enclosures for noise prone machinery and/or including equipment supports with dampers. Reduction of noise from services is particularly appropriate in industrial buildings.

National regulations may specify acoustic performance standards in terms of reducing noise coming into a building – but these are often for residential buildings. 65 dB is generally considered a suitable indoor noise level in industrial buildings, whereas 50 to 55 dB is considered a suitable indoor ambient noise level for commercial, retail and leisure buildings. For industrial buildings, noise break-out is usually a greater concern. Local regulations may specify acoustic requirements to reduce noise break-out from within a building (for example if the building is sited adjacent to a residential area).

Cladding system manufacturers will be able to provide acoustic performance data for different constructions, and be able to recommend a system to meet the specification.

A built-up system comprising an inner and outer sheet of pre-finished steel with mineral wool insulation generally achieves over 40 dB of sound reduction. Rock mineral wool has a greater density than glass mineral wool, and generally improves the sound insulation. Sound insulation can be improved by including a layer of dense acoustic mineral wool slab, in addition to the insulation quilt.

In general, factory insulated foam filled composite systems are not as effective as built up systems, because of the low mass of the foam core and the direct coupling of the inner and outer skins.

The sound reduction index R_w for various systems is shown in Table 3.3. A higher index indicates higher sound reduction.

Table 3.3 Sound reduction index for typical cladding systems

Cladding type	Sound reduction index R_w
Built-up system – with rock wool and acoustic insulation	47
built-up system with rock wool	45
built-up system with glass mineral wool	41
composite panel with mineral wool	31
composite panel with foam	25
single skin	24

3.5.5 Further information

Further guidance is available in MCRMA Technical paper No. 8 *Acoustic design guide for metal roof and wall cladding*[8] and also from ECCS-TC7 Publication 41 *Good practice in steel cladding and roofing*[6].

3.6 Fire performance

In general, any concerns about the reaction of cladding to fire are far outweighed by concerns about the smoke and gas generated by the contents of the building, not the envelope.

Single sheet cladding is considered to contribute significantly to any fire. Single sheet cladding is generally assumed not to make any contribution to fire resistance, although in practice some integrity and resistance will be provided. Single skin sheeting is generally not used on boundaries, when prevention of fire spread to neighbouring structures is important.

Built-up systems that use mineral wool or glass wool insulation are not considered to contribute significantly to any fire. Built-up systems may also be specified to meet the requirements for external envelope applications. Composite panels that use mineral wool fall in the same category.

Factory insulated composite panels may use polyurethane (PUR) or polyisocyanurate (PIR). It is generally considered that PIR panels have improved performance in fire compared to PUR panels. The core of either type of panel is difficult to ignite. Panels with appropriate joint designs with either PUR or PIR filling do not present an undue fire risk, and PUR panels are the standard core in many European countries.

Polystyrene filled panels present a fire risk, and their use is diminishing.

3.7 Durability

All cladding systems suffer a certain degree of degradation over time due to moisture, atmospheric pollution and UV radiation. However, the cladding specifier can have a considerable influence on the long term performance of the cladding through careful selection of materials and good detailing. Once in service, regular maintenance will prolong the life of the building envelope.

The metal from which the weather sheet is made is available with several types of coating with a wide variety of colours and finishes. Guidance on the expected design lives of these coatings is available from MCRMA Technical paper No. 6 *Profiled metal roofing design guide*[4] and also from ECCS-TC7 Publication 41 *Good practice in steel cladding and roofing*[6]. It is worth noting that the colour of the coating has a very significant impact on its design life. Light colours reflect thermal radiation more efficiently than dark colours, resulting in lower surface temperatures and a reduction in the degradation experienced by the coating.

When detailing the building envelope, particular attention should be given to the avoidance of water and dirt traps by specifying suitable slopes and end laps. Careful detailing is needed at the external interfaces to avoid the ingress of water and at the internal interfaces to prevent water vapour from within the building entering the cladding assembly (resulting in interstitial condensation).

In order to ensure that the building envelope remains fully functional throughout its design life, it is important that it receives regular maintenance, including inspection, removal of debris, cleaning and repair of damage. Since maintenance usually involves access by workmen, often carrying equipment, it is essential that this is allowed for in the design of the building envelope and the supporting structure. The need for maintenance may be greatly reduced by specifying a coating for the weathersheet with a ‘maintenance free’ guarantee for the expected design life of the cladding (typically 20 to 30 years). Such coatings can provide significant benefits to the client in terms of whole life costs and improved safety.

3.8 Structural performance

Metal cladding systems are required to carry externally applied loads, such as snow and wind loading without deflecting excessively or compromising the other performance requirements. The individual characteristic loads (actions) should be obtained from the appropriate part of EN 1991[9], taking into account the building geometry and location as applicable. These individual actions should then be combined using the appropriate safety factors from EN 1990[10] to obtain the load cases used in design.

3.8.1 Actions

Permanent actions

For most industrial and commercial applications of metal cladding technology, the only permanent action for which the roof cladding needs to be designed is its own self-weight, including the weight of the insulation. Typical weights of insulated panels and built-up cladding systems are given in Table 3.4. For information on specific cladding products, designers should consult the technical literature available from manufacturers or suppliers. For wall cladding, it is not normally necessary to consider permanent actions, since the self-weight acts in the plane of the cladding. However, where a rainscreen system is attached to the outer face of the cladding panel or assembly, it will be necessary to consider the impact of the rainscreen system weight when specifying the fasteners.

Table 3.4 Typical cladding system weights

System	Insulation	Depth*	Sheet thickness		Weight kN/m^2
			Inner	Outer	
Built-up	Mineral wool	180 mm	0,4 mm	0,7 mm	0,16
Built-up	Mineral wool	180 mm	0,7 mm	0,7 mm	0,20
Insulated Panels	PIR	80 mm	0,4 mm	0,5 mm	0,12

* The depths chosen in Table 3.1 correspond to a U-value of 0,25 W/m^{2}K for typical cladding systems using the insulation shown.

Variable actions

In addition to its self-weight, the roof cladding must also be designed for the following variable actions as specified in the appropriate parts of EN 1991:

- Access for cleaning and maintenance
- A uniformly distributed load due to snow over the complete roof area. The value of this load will depend on the building’s location
- Asymmetric snow load and loading due to snow drifts
- Wind pressure and suction.

Care should be taken when ‘green’ roofs are specified, as they tend to be considerably heavier than traditional metal roofs and, in the case of roof gardens, must be designed for the presence of garden furniture and people.

Wall cladding should be designed for wind loading according to EN 1991-1-4[9]. Positive wind pressure and wind suction will need to be considered, with special attention paid to the areas of high wind suction close to the corners of the building. The wind suction design case is often governed by the resistance of the fasteners connecting the cladding panels or sheets to the supporting steelwork.

3.8.2 Deflections

The cladding must be capable of carrying the specified design loads without deflecting excessively, if the other performance requirements such as weathertightness, airtightness and durability are to be achieved. The predicted deflections are normally calculated for the unfactored variable actions only. Loading at the construction stage is not normally included in the serviceability load cases and is not normally considered when specifying cladding systems. However, care must be taken on site to avoid excessive local deflections, especially those caused by concentrated loads such as foot traffic or stacked materials on roof liner sheets, as these could result in permanent damage to the cladding. Typical deflection limits imposed on the cladding are dependent on the loading regime considered (imposed load only or permanent plus imposed loading), the location (wall or roof) of the structural component and whether a brittle material is present. Deflection limits may be specified by National regulations. Common deflection limits are:

- Span/150 for wall cladding, spanning between secondary steelwork
- Span/200 for roof cladding, spanning between purlins
- Span/180 for purlins or side rails.

3.8.3 Use of safe load tables

The manufacturers of profiled metal sheeting and insulated panels provide safe load tables for their products, which may be used either to select a suitable profile or, where the profile has already been chosen, to determine the maximum permissible purlin spacing. It is important to note that the load tables often assume that the loading is uniformly distributed and that safe working loads are usually specified. If in doubt, specifiers should seek guidance from the cladding manufacturers.

4 COLD ROLLED SECONDARY STEELWORK

For steel portal framed industrial type buildings with low pitch roofs (5 to 10 degrees), the cladding panels or sheets are normally supported by a system of light steel purlins and side rails spanning between the rafters and columns respectively. See Figure 4.1 showing secondary steelwork in the roof where the purlins span between the rafters of the main frame. The primary function of these secondary members is to transfer load from the cladding to the primary steel frame, including cladding self-weight, wind loads and, for roofs, imposed loads due to snow and maintenance access. The purlins and side rails may also be used to provide restraint to the rafters and columns and to transfer horizontal loads into the bracing system.

Figure 4.1 Purlins spanning between rafters in the roof

This Section presents guidance on some of the key issues relating to the use of cold formed purlins and cladding rails.

4.1 Purlin and side rail options

Purlins and side rails are generally cold formed light gauge galvanized steel members, supplied as part of a proprietary cladding support system, together with fittings, fasteners and other associated components.

4.1.1 Section options

Purlins and side rails are available in a variety of shapes and a wide range of sizes. The depth of the section typically lies between 120 mm and 340 mm, with the profile thickness varying between 1,2 mm and 3,2 mm. Some of the more common section shapes are shown in Figure 4.2. Purlins and side rails, because of their high length/thickness values, are typically classed as Class 4 sections as defined in EN 1993-1-3[11], hence section properties will be need to be based on effective values (reduced gross properties).

Further information on these sections may be obtained from the manufacturers' technical literature.

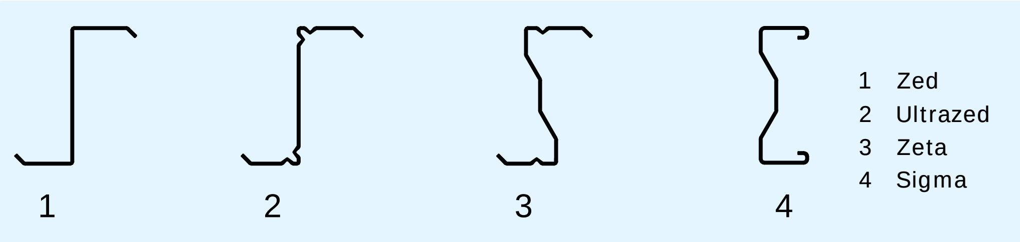


Figure 4.2 Common types of purlin

4.1.2 Purlin and side rail layout options

Most manufacturers produce guidance on typical purlin layouts that are efficient for various situations. These layouts are governed by such aspects as maximum purlin length (generally not more than 16 m for transport and site access reasons) and the ability to provide semi continuity by the use of sleeves or overlaps for maximum efficiency. The most commonly used layouts are shown in Figure 4.3 to Figure 4.7. Specifiers seeking further information on when and how to use a particular layout should consult the purlin manufacturers for detailed information relating to their specific systems. In any event, the purlin manufacturer should be consulted before the layout is finalised.

Single-span lengths - sleeved system

In sleeved systems, each purlin is the length of a single span but sleeves are provided at alternate supports so that each purlin is effectively continuous across two spans (Figure 4.3). At the penultimate support, sleeves are provided at each purlin, to provide semi continuity and additional strength in the end bay. This system is considered to be the most efficient for buildings with bay centres between 5 m and 7 m. Heavier sections can be provided in the end bay if necessary.

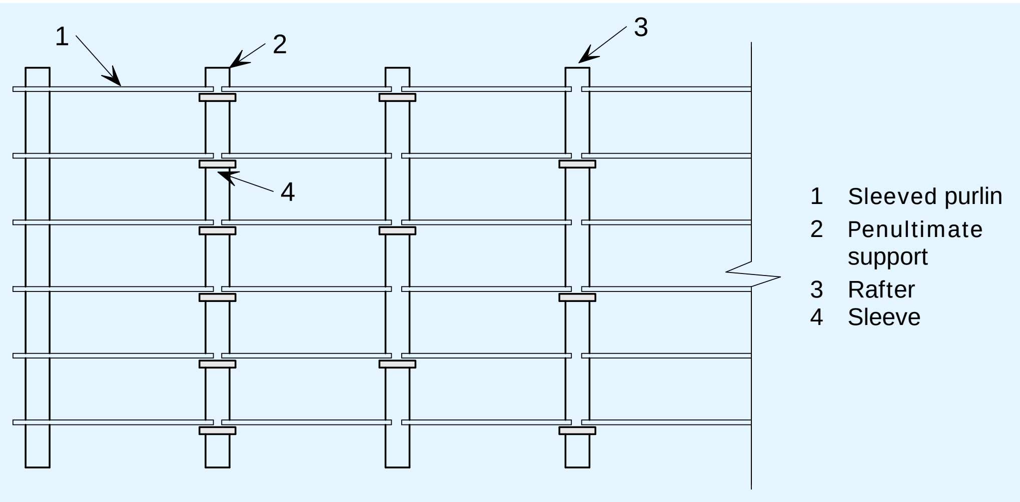


Figure 4.3 Single-span lengths – sleeved system

Single-span lengths - butted system

Single-span butted systems have a lower capacity than the other systems, but are simpler to fix either over the rafters or between rafter webs (Figure 4.4). This layout may be used for small buildings with close frame centres, such as agricultural applications.

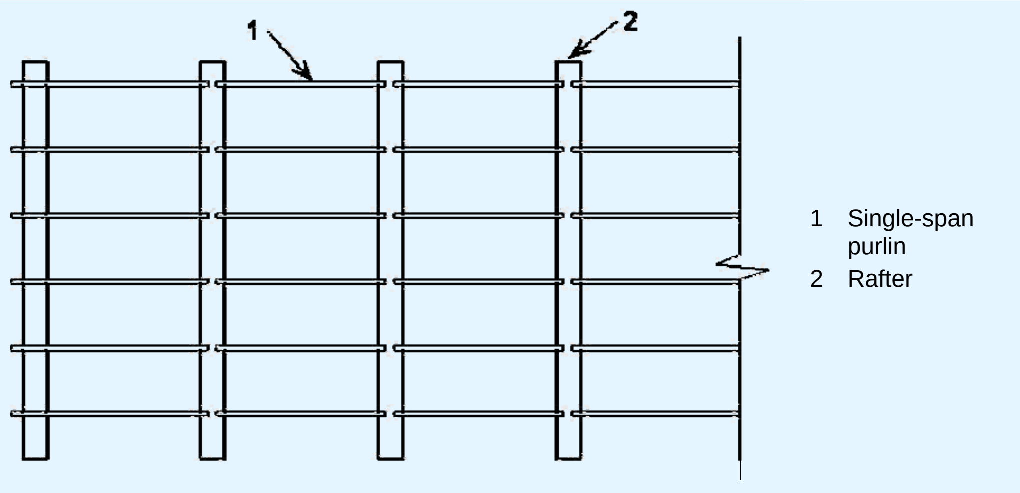


Figure 4.4 Single-span lengths - butted system

Single-span lengths - overlapping system

An overlapping system provides greater continuity and can be used for heavy loads and long spans (Figure 4.5). It is best suited to buildings with a large number of bays.

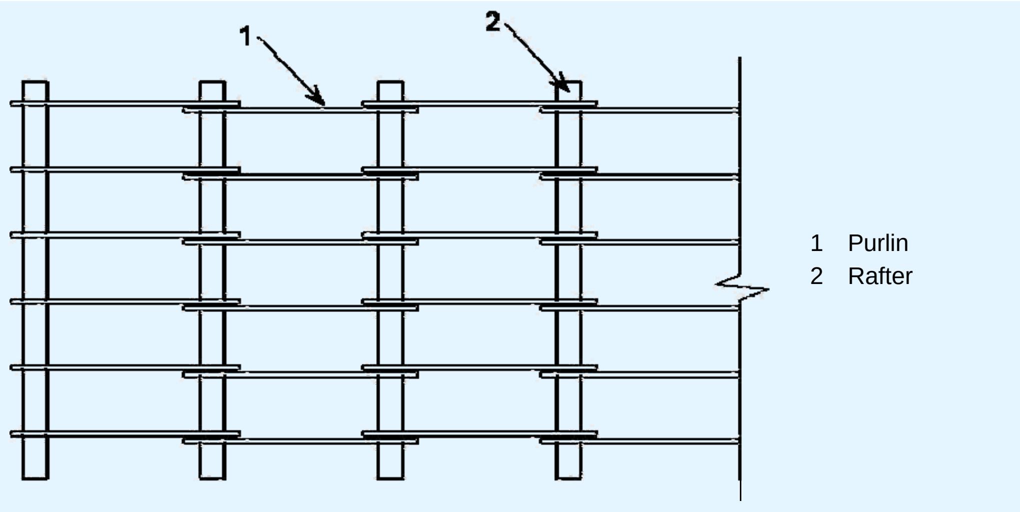


Figure 4.5 Single-span lengths - overlapping system

Double-span lengths – non sleeved system

In this system, the double-span lengths are staggered (Figure 4.6). Sleeves are provided at the penultimate supports to ensure semi continuity. The capacity will generally be less than for the equivalent double span sleeved system, but double-span purlins use fewer components and lead to faster erection. This system is limited to bay sizes less than 8 m, for reasons of transport and erection of the purlins.

Figure 4.6 Double-span lengths – non sleeved system

Double-span lengths - sleeved system

In double-span sleeved systems, the double-span lengths are staggered and sleeves are provided at alternate supports (Figure 4.7). Sleeves are provided to every purlin at the penultimate support to ensure semi continuity. A double span sleeved system has a slightly higher capacity than the double-span non-sleeved system and has the advantages of semi continuity at all sleeve positions. This system is limited to bay sizes less than 8 m, for reasons of transport and erection. Heavier purlins can be provided in the end bays, if necessary.

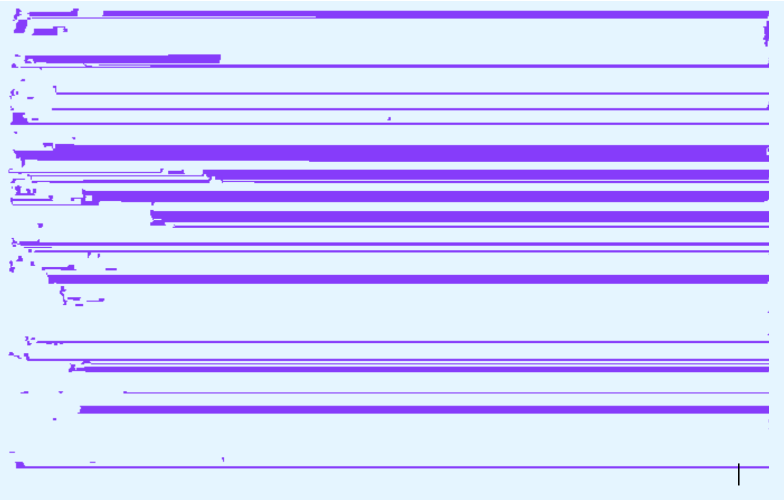


Figure 4.7 Double span lengths - sleeved system

4.1.3 The use of anti-sag rods for purlins

Anti-sag rods are small rods or angles that are bolted or clipped between the purlins. A typical arrangement is shown in Figure 4.8; other systems are also available. When used, they are commonly placed either at mid-span or at third points along the purlin and serve the following functions:

- They provide restraint to the purlins against lateral-torsional buckling under wind uplift conditions