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## **Best Practice for the Specification and Installation of Metal Cladding and Secondary Steelwork**

**Building Envelopes**



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# **Best Practice for the Specification and Installation of Metal Cladding and Secondary Steelwork**

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# FOREWORD

Changes to Part L of the Building Regulations in England and Wales in recent years have resulted in a greatly increased thickness of insulation in roof and wall cladding for most types of building structures. The 2002 version of Part L also introduced into the Building Regulations requirements for limiting air leakage through the building envelope, placing higher demands on the specifiers and installers of cladding systems and the supporting secondary steelwork in terms of construction quality and tolerances.

It was against this background that the Steel Construction Institute (SCI) commenced work on a DTI 'Partners in Innovation' project entitled "What are the Regulatory changes doing to our structures?" with the specific aim of investigating the impact of the Part L changes on the structural performance of buildings. Of particular interest was the interaction between the cladding and the steelwork, including the restraint provided to the purlins and side rails in the wind uplift condition. The project also considered the secondary steelwork tolerances that would be required to meet the anticipated tightening of air leakage limits and several issues relating to the installation of metal cladding systems and secondary steelwork. The project was jointly funded by the DTI, Corus, the Metal Cladding and Roofing Manufacturers Association (MCRMA) and Engineered Panels in Construction (EPIC).

An industry group including representatives of the MCRMA, EPIC, the National Federation of Roofing Contractors (NFRC), Cold Rolled Sections Association (CRSA), British Constructional Steelwork Association (BCSA) and the National Association of Rooflight Manufacturers (NARM) was formed to address the issues mentioned above. Over a period of 2 years, agreement was reached on a range of topics covering many aspects of specification and installation, culminating in the drafting of good practice guidance aimed at designers and installers of metal cladding systems and secondary steelwork. This publication is the end-product of that process.

The publication was written by Dr Martin Heywood of SCI. Valuable contributions to the technical content of the publication were made by the industry group, the members of which are listed overleaf. The publication draws on an extensive reference list of existing publications by SCI and others, covering a range of topics relating to the specification and installation of building envelope systems. A full list of these references is included in Section 7.

This publication and the research leading to it were jointly funded by the DTI (through the Partners in Innovation programme), Corus, the MCRMA and EPIC.

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## SUMMARY

This publication presents guidance to designers and contractors on the specification and installation of profiled metal cladding systems and the supporting purlins and side rails. Built-up cladding systems and insulated panels are both considered, but single-ply membranes supported by structural decks are outside the scope of the publication.

The guidance covers many aspects of cladding specification, including a brief description of the available systems and their components and an overview of the various performance criteria that should be considered by the specifier. These include weathertightness, appearance, thermal performance, acoustics, durability and structural capacity. Particular attention is paid to the structural performance of the cladding, since inadequate strength and stiffness not only undermine the safety of the building, but also impact on several of the other performance criteria such as airtightness and durability.

The specification of the purlins and side rails is usually achieved by reference to manufacturer's safe load tables and supporting technical information. However, there are several important issues that need to be brought to the attention of the secondary steelwork designer in order to ensure a safe and efficient structure. In particular, there is a need for good interaction between the building elements, especially in relation to the provision of lateral and torsional restraint.

The sections on cladding and purlin installation provide an overview of the issues that need to be addressed in order to meet the performance criteria identified by the building designer. Many of the issues covered in this publication have been brought to the attention of the SCI by industry representatives, whose advice and knowledge is the foundation for the guidance presented herein. The aim of the guidance is to promote good practice across the industry, leading to improvements in Health and Safety, efficiency and building envelope performance. Although written with site practitioners in mind, much of the guidance should also be useful to architects and structural engineers involved in the specification of the building envelope and supporting structure.

### **Bonne pratique concernant les spécifications et l'installation de bardages métalliques et d'éléments secondaires de structures en acier**

#### **Résumé**

*Cette publication est destinée à servir de guide pour les projeteurs et contractants concernant la spécification et l'installation de bardages métalliques et des pannes et lisses qui supportent ces bardages. Les bardages posés sur place et les panneaux isolants sont pris en compte. Toutefois, les membranes supportées par des planchers ne sont pas considérés dans cette publication.*

*Le guide couvre divers aspects de la spécification des bardages, y compris une brève description des systèmes disponibles et de leurs composants et une revue des différents critères de performances qui doivent être pris en compte par le spécificateur comme, par exemple, l'étanchéité, l'aspect, les performances thermiques, l'acoustique, la durabilité et la résistance. Une attention particulière est donnée aux performances structurales des bardages car une résistance et une rigidité inadéquates entament non seulement la sécurité du bâtiment mais a aussi un impact sur d'autres critères de performance comme l'étanchéité à l'air et la durabilité.*



*Les spécifications concernant les pannes et les lisses sont généralement rédigées par référence aux tables et aux informations techniques données par les fabricants. Cependant l'attention du projeteur doit être attirée sur certains points. En particulier, il est nécessaire d'arriver à une bonne interaction entre les différents éléments de la construction, en particulier pour assurer une bonne restrainte latérale et torsionnelle des profils.*

*Les chapitres consacrés à la mise en œuvre des bardages et pannes passent en revue les points qui doivent être pris en compte pour atteindre les critères de performances spécifiés. Plusieurs de ces points ont été portés à l'attention du SCI par les représentants de l'industrie, dont l'expérience a beaucoup aidé à la rédaction de ce guide. Le but de cette publication est de promouvoir une bonne pratique industrielle, conduisant à une amélioration de la santé et de la sécurité et de l'efficacité de la construction. Bien que conçue d'abord en pensant aux praticiens de chantier, une large part de cette publication sera également utile aux architectes et aux ingénieurs de bureaux d'études impliqués dans les spécifications relatives à l'enveloppe d'un bâtiment et la structure supportant cette dernière.*

## **Beste Vorgehensweise bei Leistungsbeschreibung und Montage von Metallbekleidungen und der Unterkonstruktion aus Stahl**

### **Zusammenfassung**

*Diese Publikation bietet eine Anleitung für Planer und Auftragnehmer für die Leistungsbeschreibung und Montage von Metallbekleidungen und der Unterkonstruktion aus Pfetten und Randprofilen. Es werden zusammengesetzte Systeme und gedämmte Paneele berücksichtigt, nicht aber einschalige, auf tragender Unterlage verlegte Bekleidungen.*

*Die Anleitung beinhaltet viele Aspekte der Planung, einschließlich einer kurzen Beschreibung der verfügbaren Systeme und ihrer Komponenten sowie einen Überblick der verschiedenen Verhaltenskriterien die vom Planer berücksichtigt werden sollten. Diese beinhalten Wetterbeständigkeit, Erscheinungsbild, thermisches Verhalten, Akustik, Dauerhaftigkeit und Tragvermögen. Besondere Aufmerksamkeit gilt dem Tragverhalten der Bekleidung, da unzureichende Festigkeit und Steifigkeit nicht nur die Sicherheit des Gebäudes untergraben, sondern auch zahlreiche andere Verhaltenskriterien beeinflussen, wie Luftdichtigkeit und Dauerhaftigkeit.*

*Die Festlegung der Pfetten und Randprofile wird üblicherweise anhand von Herstellertabellen und technischen Informationen vorgenommen. Es gibt jedoch mehrere wichtige Punkte, die beim Nachweis der Unterkonstruktion beachtet werden müssen, um eine sichere und wirtschaftliche Konstruktion zu gewährleisten. Insbesondere kommt es auf eine gute Interaktion zwischen den Gebäudeelementen an, vor allen Dingen ist die Festlegung der Auflagerbedingungen wichtig.*

*Die Abschnitte über Bekleidung und Unterkonstruktion geben einen Überblick über die zu beachtenden Punkte, damit die Anforderungen des Gebäudeplaners erfüllt werden. Viele der in dieser Publikation enthaltenen Punkte sind dem SCI von Industrievertretern zu Ohren gekommen, deren Ratschläge und Wissen das Fundament für diese Anleitung ist. Das Ziel dieser Anleitung ist es, gute Ausführungsqualität bei den Auftragnehmern zu fördern, die zu Verbesserungen bei Gesundheit und Sicherheit, bei Effizienz und Bauteilverhalten führen. Obwohl mit Unterstützung von Baupraktikern geschrieben, sollte diese Anleitung auch für Architekten und Ingenieure nützlich sein, die mit der Leistungsbeschreibung von Gebäudehüllen und deren Unterkonstruktion beschäftigt sind.*

## **Normas de buena práctica para los pliegos de condiciones y normas de instalación de revestimientos metálicos y obra metálica secundaria**

### **Resumen**

*Esta publicación es una guía para proyectistas y constructores sobre los pliegos de condiciones y normas de instalación de revestimientos metálicos, sus correas de soporte y sus carriles de contorno. Se consideran tanto sistemas premontados como aislados pero las membranas soportadas por tableros estructurales están fuera del alcance de la publicación.*

*La guía cubre muchos temas de las especificaciones del revestimiento incluyendo una breve descripción de los sistemas existentes y sus componentes y un panorama de los diferentes criterios a considerar por el proyectista. Éstas incluyen la estanqueidad, el aspecto, el comportamiento térmico, la acústica, la durabilidad y la capacidad estructural. Se pone énfasis especial en el comportamiento estructural del revestimiento puesto que la resistencia o rigidez inadecuadas no solo afectan la seguridad del edificio sino que repercuten también en varios otros tipos de prestaciones como la durabilidad o la estanqueidad.*

*Las condiciones sobre correas o carriles de contorno se realizan habitualmente mediante envío a tablas de seguridad e información técnica complementaria producida por el fabricante. Sin embargo hay diferentes temas de importancia a los que el proyectista de la obra metálica secundaria se necesita dedicar atención para asegurar la seguridad y eficiencia de la estructura.*

*En especial se precisa una buena interacción entre los elementos del edificio, especialmente en lo relativo a la disposición de coacciones lateral y de torsión.*

*Los apartados dedicados a instalación de revestimientos y correas dan un panorama sobre los temas a tratar para conseguir criterios de prestaciones identificados por el proyectista del edificio. Muchos de los aspectos tratados en la publicación han sido sometidos a la atención del SCI por representantes de la industria cuyo consejo y experiencia es la base de las recomendaciones aquí recogidas. El propósito de la guía es la promoción de buenas prácticas en la industria que conduzcan a la mejora de Salud y Seguridad, y a la eficiencia de prestaciones en la envolvente del edificio. Aunque escrito con la intención de ayudar a los instructores a pie de obra mucho del contenido puede ser útil a arquitectos e ingenieros de estructuras dedicados a estos temas.*

## **Regole di buona pratica per capitolati e installazioni di tamponamenti in acciaio e componenti secondarie**

### **Sommario**

*Questa pubblicazione presenta una guida per i progettisti e gli appaltatori sia su capitolati ed installazioni di sistemi di tamponamento con profilati in acciaio sia su elementi di supporto e sostegni laterali. Vengono considerati sia sistemi di tamponamento composti sia pannelli di isolamento mentre esulano dalla presente trattazione gli stati isolanti singoli posizionati sulla lamiera grecata.*

*La guida tratta i diversi aspetti associati alle specifiche dei tamponamenti e propone una breve descrizione dei sistemi disponibili e delle loro componenti e una panoramica dei vari criteri prestazionali che dovrebbero essere forniti dai produttori, con particolare riferimento a capacità isolante, prestazioni termiche e acustiche, durabilità e resistenza strutturale. Particolare attenzione è prestata alle prestazioni statiche dei tamponamenti in quanto resistenza e rigidità inadeguate non solo influenzano la sicurezza dell'intero*

*edificio ma anche impattano su altri aspetti prestazionali importanti come la tenuta stagna e la durabilità*

*I capitolati relativi agli arcarecci ed alle guide laterali sono usualmente ottenuti dai riferimenti alla tabelle di portata dei produttori e dalle informazioni tecniche di corredo. Esistono comunque importanti indicazioni che devono essere tenute in conto dai progettisti di elementi secondari in modo da garantire una struttura sicura ed efficiente. In particolare deve essere garantita una corretta interazione con gli elementi dell'edificio, specialmente in relazione alle esigenze di vincolo laterale e torsionale.*

*La parte dedicate all'installazione di tamponamenti e arcarecci fornisce una panoramica sui requisiti peculiari necessari per garantire i criteri prestazionali richiesti dai progettisti. Molte di queste indicazioni accolte dallo Steel Construction Institute sono risultate precise esigenze dei rappresentanti dell'industria.*

*Lo scopo della guida è quello di promuovere un buon utilizzo di queste componenti, per una migliore utilizzo dell'edificio tenendo in conto gli importanti parametri associati a salute e sicurezza. Sebbene quanto riportato è presentato nell'ottica di un utilizzo da parte di tutte le figure professionali attive nella realizzazione di un edificio, una gran parte della guida può essere di diretta utilità anche per architetti ed ingegneri coinvolti nello sviluppo del capitolato dell'edificio e delle componenti accessorie.*



# 1 INTRODUCTION

## 1.1 Background

Metal cladding systems supported by light gauge secondary steelwork provide an efficient, attractive and reliable solution to the building envelope needs of steel framed buildings. Over the years, they have evolved from the single skin metal cladding often associated with agricultural buildings to highly developed built-up systems and insulated panels used in industrial, retail and leisure applications across the United Kingdom. However, as with all construction components, the ability of the cladding to satisfy its functional requirements is dependent on its correct specification and installation and, equally as important, on its interaction with the other elements of the building envelope and structure.

Recent changes to Part L of the Building Regulations<sup>[1]</sup> in England and Wales have increased the energy performance requirements of buildings, thereby increasing the demands on the cladding system. Reduced air leakage limits are one specific example of this. Furthermore, the cumulative changes to the Building Regulations have resulted in an increase in insulation thickness to the point where structural engineers are beginning to question some of the traditional assumptions regarding the structural performance of the cladding and supporting steelwork. The issues of particular concern include:

- the ability of built-up roof cladding systems to transfer down-slope loads to the purlins
- the ability of the cladding to restrain the purlins (or rails) against wind uplift (or suction) loads
- the secondary steelwork tolerances needed to ensure airtightness of the building envelope.

It is important to recognize that many of the leading players in the industry are already producing metal-clad buildings that exceed the requirements of the latest Building Regulations in terms of air leakage and energy performance. However, the SCI is aware of instances where problems have been encountered due to poor practices in the design office or on site. The reasons for these problems are varied, but a common theme is the lack of appreciation of the mutual dependence between the various components and, consequently, the need for greater co-operation between the members of the project team. The need for greater understanding and co-operation is particularly relevant in the light of recent regulatory changes that have resulted in a need for a higher quality of construction in order to achieve the required standard of airtightness.

## 1.2 Scope and aims of the publication

This publication gives guidance on the specification and installation of the common types of profiled metal cladding system currently in use in the United Kingdom. These systems include insulated panels and built-up systems for roofs and walls. The publication also gives guidance on the specification and installation of the supporting purlins and side-rails, and considers how this secondary steelwork interacts with the cladding to produce a safe, functional and efficient structure.

The publication is aimed at specifiers, designers and site erectors. Its principal aim is to present best practice guidance on all of the relevant aspects of modern cladding design and installation. By combining this information into one volume, it is intended to achieve the widest possible dissemination across the many disciplines and trades involved in the production of the building envelope. Furthermore, it is hoped that this approach will promote a greater understanding of the issues faced by the various members of the construction team and lead to greater co-operation on site and in the design office.

The individual components that make up the cladding system are often specified and supplied separately, with insufficient attention paid to the way in which they interact. Some of the design assumptions relating to the interaction between components are based on tests performed during early development work in the 1970s and 1980s, when cladding systems were much thinner than they are today. One of the aims of this publication is to show which of these assumptions are still valid, following the changes to the regulations and the resulting increase in insulation thickness.

Some of the guidance presented in this publication is the result of a recent study by The Steel Construction Institute (SCI) into the major issues facing the cladding sector of the construction industry, while other aspects have been drawn together from existing guidance published by the SCI, the Metal Cladding and Roofing Manufacturers Association (MCRMA), the National Federation of Roofing Contractors (NFRC) and other similar bodies. A full list of references is presented in Section 7.

**Certain sentences/paragraphs within the publication merit special emphasis and are highlighted in bold coloured ink. These key points are repeated in Section 6.**

## **1.3 The building envelope**

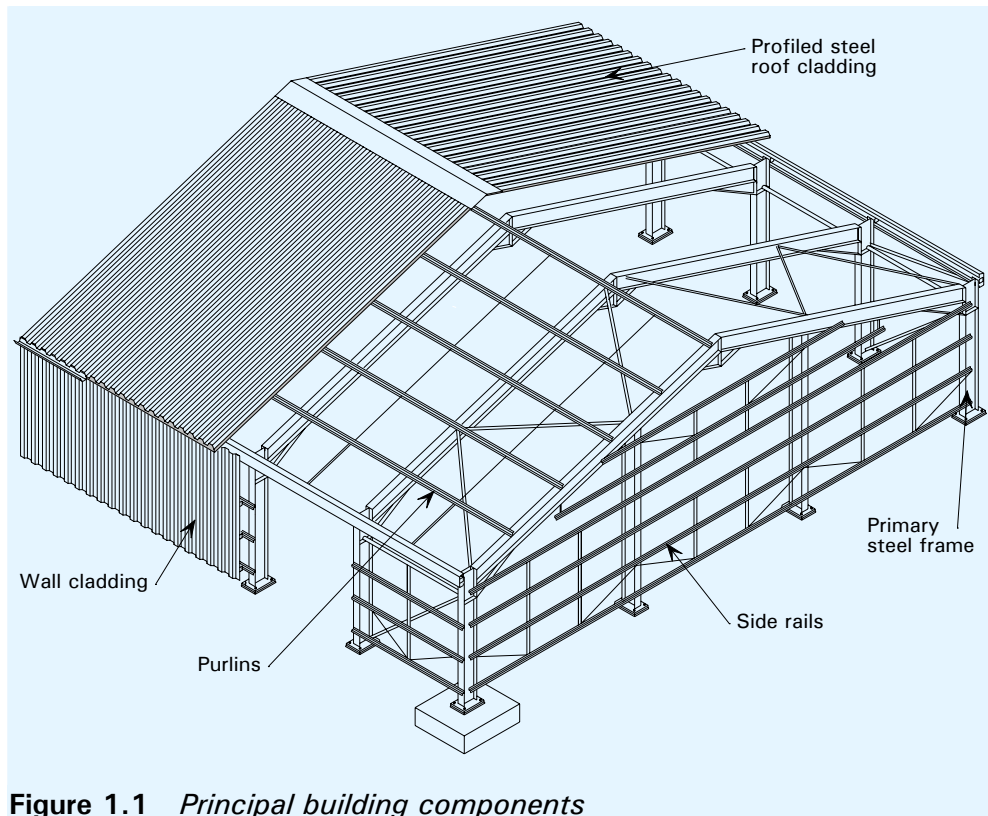
### **1.3.1 The principal building components**

The principal components of a modern metal-clad industrial type building are shown in Figure 1.1.

There are essentially three layers to the structure:

1. The primary steel frame, consisting of columns, rafters and bracing. The example shown in Figure 1.1 is constructed from portal frames, but the guidance given in this publication is equally applicable to other types of frame.
2. The secondary steelwork, consisting of side-rails and purlins. These members serve three purposes:
  - (a) To support the cladding
  - (b) To transfer load from the cladding to the primary steel frame
  - (c) To restrain the primary steel frame members.
3. The roof and wall cladding, whose functions include some or all of the following:
  - (a) Separating the enclosed space from the external environment
  - (b) Transferring load to the secondary steelwork

- (c) Restraining the secondary steelwork
- (d) Providing thermal insulation
- (e) Providing acoustic insulation
- (f) Preventing fire spread
- (g) Providing an airtight envelope.



**Figure 1.1** *Principal building components*

The cladding will normally include ancillary components such as windows, rooflights, vents and gutters.

A key message to note is that the efficient structural design of the building is dependent as much on the interaction between these components as it is on their individual performance. Designers must, therefore, take a holistic approach to the design of the structure, rather than specifying each element in isolation, or relying on others to choose some of the components.

### **1.3.2 The functions of building envelope**

All buildings, whatever their use, must provide a controlled internal environment that is protected from the variable and uncontrollable external climate. The nature of the internal environment will depend on the intended use of the building and this will naturally determine the requirements for the building envelope. At one end of the scale, for example an agricultural building, the only requirement for the building envelope is to keep the enclosed space dry. By contrast, an office building will require accurate control of the internal temperature and humidity, and provision of appropriate levels of daylight, in order to provide a pleasant working environment for the building occupants.

Generating and maintaining a controlled internal environment is a complex process, requiring a combination of mechanical and electrical services to heat and/or cool the building and a well-designed building envelope to regulate the heat gain and loss. The design of the building envelope is an important factor in specifying the M&E plant and in determining the energy performance of the building. With pressure to reduce energy consumption now being placed on the construction industry by the United Kingdom Government in an attempt to reduce the levels of greenhouse gas emissions, the building envelope has never before been under such close scrutiny.

In addition to forming the building envelope, the roof and wall cladding may also have an important role to play in the structural performance of the building, by providing restraint to the secondary steelwork against lateral-torsional instability. Where such restraint is assumed (as is often the case in the purlin and side-rail manufacturers' load/span tables), it is essential that the cladding is capable of providing this restraint in practice. This issue is discussed in detail in Section 3 of this publication.

### **1.3.3 Types of cladding system**

There are many types of roof and wall cladding system for the architect to choose from, but the focus of this publication is on the modern twin skin built-up assemblies and insulated panels made from profiled steel sheets. These cladding systems dominate the market for industrial type buildings, because of their cost effectiveness, the speed with which they can be installed, their ability to offer restraint to the structural members, their ability to withstand deflections without damage and their good thermal performance. The use of profiled steel sheeting is also common in other applications such as large retail outlets and leisure facilities.

Roof systems comprising deep structural decking, a layer of insulation and a waterproof membrane, as often used on flat roofs, are outside the scope of this publication.

## **1.4 The project team**

In much the same way that efficient structural design relies on good interaction between the various components that make up the building structure (primary steelwork, secondary steelwork and cladding), so the efficiency and safety of the design and construction processes depend on good interaction between members of the project team. This is especially important with the building envelope, since its design and construction usually require input from several organizations and many individuals. This section identifies the key players and highlights their primary roles and responsibilities.

### ***Client***

The Client is the person or organisation procuring the building. Client organisations can be private sector developers, whose main business is the procurement and resale (or lease) of buildings, other private sector businesses, such as retailers or wholesale distributors, or public sector organizations. The type of client will determine the roles and responsibilities undertaken during the project. While some organizations prefer to appoint external designers (architects and structural engineers), others employ their own design staff to perform the conceptual design and develop the specification.



### ***Architect***

In traditional building contracts, the Architect is the person or organization with responsibility for the overall design of the building, including internal layout, functional performance and external appearance. Although the Architect does not normally carry out the structural design, decisions taken by the Architect will often determine the structural form of the building (e.g. the required column spacing and permitted bracing locations). The Architect is usually the person who specifies the roof and wall cladding, although this is not always the case, e.g. in some “Design and Build” contracts.

### ***Structural Engineer***

The Structural Engineer is the person or organization with responsibility for the structural design of the permanent works, including the requirements under the *Construction (Design and Management) Regulations*<sup>[2]</sup> to ensure that the structure can be erected and demolished in a safe manner. Depending on the nature of the contractual arrangements between the Client and the other parties, this role could be performed by a Consultant, by a “Design and Build” Contractor or by a specialist Steelwork Contractor. Frequently, in the procurement of industrial type buildings, the detailed structural design is carried out by the Steelwork Contractor. The detailed structural design usually includes the specification of the purlins and side rails.

### ***Main Contractor***

The Main Contractor is the organization appointed by the Client to build the permanent works. Due to the varied nature of the construction activities and the specialist skills and equipment needed, it is normal practice for the Main Contractor to employ several specialist sub-contractors to perform individual tasks such as the design, manufacture, delivery, erection and cladding of the steel framed structure. However, the responsibility for all permanent works and any associated temporary works lies with the Main Contractor, as does the responsibility for Health and Safety on site.

### ***Steelwork Contractor***

The Steelwork Contractor is appointed by the Main Contractor or Client to design, manufacture, supply and erect the structural steel frame and other associated components, including the purlins and side rails. In a “Design and Build” contract, the Steelwork Contractor may be responsible for the detailed design of the steel members and their connections, in addition to the usual roles of fabrication and erection. In this case, the Steelwork Contractor assumes some or all of the responsibilities of Structural Engineer, including those under the CDM Regulations.

### ***Cladding Contractor***

The Cladding Contractor is the organization appointed by the Main Contractor or Client to install the roof and wall cladding. This work may or may not be carried out as a separate sub-contract from the steelwork erection. However, since the successful installation of the cladding is dependent on the accurate erection of the primary and secondary steelwork, it is important that the Cladding Contractor and Steelwork Contractor communicate with each other, either directly or indirectly via the Main Contractor, to avoid the risk of costly remedial work.

## ***Component manufacturers***

The building envelope consists of many components, ranging from individual fixings to large insulated panels. In the majority of cases, the person specifying the components relies on technical literature provided by the component manufacturers, including data relating to the performance of the components in service and safe load tables. In some cases, the manufacturers also provide design software or undertake design services in support of their products.

## **1.5 Safety considerations**

### **1.5.1 Legal requirements**

Under the *Construction (Design and Management) Regulations 1994*<sup>[2]</sup>, building designers have a duty to ensure that their designs give adequate regard to health and safety during construction and in service. Therefore, in addition to the functional performance requirements discussed in Sections 2.2 to 2.9, the specifiers of roof and wall cladding must also consider the hazards associated with the building's construction and operation, and select components and systems that either eliminate these hazards altogether or at least minimise the associated risks.

The principal health and safety considerations for construction and maintenance are discussed in Sections 5.2 and 1.5.3 respectively, together with guidance on how to minimise risk through practical design measures. Designers should also consider the hazards associated with the demolition and disposal of the building and its materials, but this is outside the scope of this publication.

### **1.5.2 Safety during construction**

Many of the hazards associated with the construction of the building envelope arise from the need to work at height. This is especially true for roof cladding operations. The two principal categories of hazard are:

- Falls through 'fragile' roofs or gaps in the roof
- Falls from the edge of the roof.

Practical measures that may be taken on site to minimise the risks associated with these hazards are discussed in Section 5.5, but there are also a number of steps that can be taken by the design team.

Firstly, the cladding specifier should ensure that the specified roof assembly is 'non-fragile' (see Section 5.5.2). This is an important consideration for construction and maintenance. Where built-up cladding systems are used, it is also advisable to specify a liner sheet that will be non-fragile when acting alone, in order to provide a barrier against falls during the installation of the spacer system, insulation and weather sheet. The 'non-fragile' status of cladding products or assemblies should not be assumed without supporting evidence, usually in the form of test results obtained by the cladding manufacturer. The publication ACR[M]001:2005 *Test For Non-Fragility of Profiled Sheeted Roofing Assemblies*' (third edition)<sup>[3]</sup> presents detailed recommendations for the execution of fragility tests.

At times during the construction of the roof, there will be completed areas of cladding adjacent to large gaps or areas that have yet to be clad. This situation is potentially very dangerous to the operatives working on the roof. While this

hazard cannot be eliminated completely until the completion of the cladding activities, the associated risks can be significantly reduced by providing fall arrest equipment, usually in the form of safety nets or harnesses. Whichever fall arrest system is chosen, the structural engineer will need to ensure that the supporting structure is capable of carrying the additional loads.

Falls off the edge of a roof during construction may be prevented by means of temporary guardrails. These will also require consideration by the structural engineer at the design stage, in terms of the additional loading and also the provision of suitable attachment points.

Two aspects of construction safety that require input from the cladding specifier and structural engineer are the need for restraint to the supporting secondary steelwork and the ability of the cladding to provide this restraint. These issues are especially important for the roof, since the purlins are often required to support significant construction loads before the cladding has been fully fixed. Where the ability of the structure to safely support the partly-constructed envelope and the weight of the operatives installing it depends on the contractor following a specific cladding sequence, this sequence should be shown on the appropriate contract drawings. Dialogue between the structural engineer and cladding specifier is essential, since not all types of cladding are able to provide the same level of restraint. Purlin and side rail restraint is discussed further in Section 3.6.

### **1.5.3 Safety during maintenance**

Roofs are often used as a means of access for maintenance during the lifetime of the building, giving rise to similar hazards to those encountered during the construction of the roof, i.e. falls through fragile roofs and falls from the edge of roofs. Both categories of hazard are responsible for deaths and serious injuries in the UK each year and both need to be addressed during the building design process. The following points should be considered:

- Minimise the need to access the roof; specify low maintenance cladding solutions.
- Specify non-fragile roof cladding materials, including rooflights.
- Provide a safe means of access to the roof; where appropriate, consider the installation of an access hatch.
- Specify safety lines or hook points for harness attachment during maintenance work.
- Provide a permanent barrier or parapet around the edge of the roof.
- Select a spacing and layout of rooflights that minimises the risk of accidental foot traffic.

## 2 CLADDING OPTIONS AND PERFORMANCE REQUIREMENTS

The specification of roof and wall cladding has implications well beyond the aesthetics and weathertightness of the building. The choice of cladding can affect many aspects of the building's performance, from its construction right through to its eventual demolition and disposal. Indeed, the fitness for purpose of the whole building could be compromised if sufficient care is not taken when specifying the cladding.

BS 5427-1:1996<sup>[4]</sup> lists the following as factors that should be taken into consideration when specifying profiled metal cladding systems:

- Weathertightness
- Strength and rigidity
- Thermal insulation
- Control of condensation
- Control of thermal movement
- Sound insulation
- Fire resistance
- Appearance
- Durability
- Cost
- Daylighting
- External attachments
- Lightning protection
- Design detailing
- Maintenance, remedial work and renewal.

Although not specifically mentioned in BS 5427-1:1996, 'Control of air leakage' should also be included in this list.

Minimum performance requirements for a number of these factors are laid down in the Building Regulations (England and Wales), Building Standards (Scotland) Regulations and Building Regulations (Northern Ireland); advice on compliance is presented in the corresponding Approved Documents. Other factors, such as appearance and daylighting, may not seem to be as critical from an engineering viewpoint, but might be crucial to the success of the building in terms of the well-being of the occupants and the acceptance of the building by the local community. It should not be forgotten that the cost of the insulated cladding in a typical commercial or industrial building is usually a significant proportion of the overall construction cost, so decisions relating to the cladding could influence the economic success or failure of the project. The cladding also has a significant impact on the operational energy requirements and, therefore, the

operating costs of the building in service, specifically heating, cooling and lighting.

This Section introduces the different types of roof and wall cladding in common use on industrial type buildings and identifies the key issues that need to be considered by the cladding specifier. The intention is to provide specifiers with an overview of the many roles of the cladding, including weathertightness, thermal performance, airtightness, acoustics, durability and structural performance. Special attention is given to the structural behaviour of cladding systems, with particular reference to the transmission of loads to the supporting steelwork and to the restraint provided by the cladding to the purlins and side rails.

## 2.1 Types of metal cladding systems

The guidance in this publication relates to cladding products made from profiled metal sheets as commonly used on industrial type buildings. The most common types of metal cladding used in the United Kingdom are “double skin” systems comprising two metal sheets with a layer of insulation between. Double skin systems can be divided into three basic categories:

- Built-up systems
- Insulated panels
- Standing seam systems.

Other types of cladding system, such as single ply membranes with structural liners, are outside the scope of this publication.

### 2.1.1 Built-up double skin cladding

This common type of cladding consists of a profiled metal liner, a layer of insulation material, a spacer system and an outer metal sheet, as illustrated in Figure 2.1. The system is built up from these components on site.

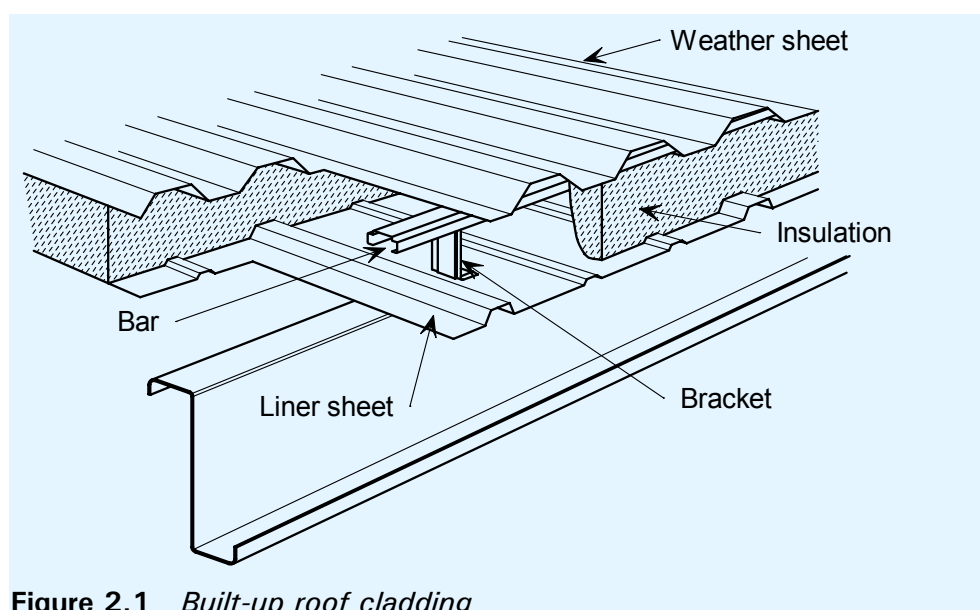


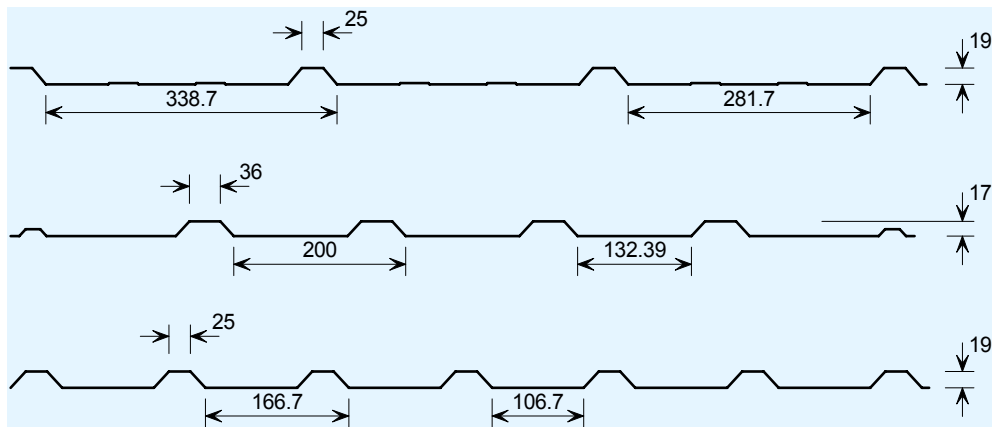
Figure 2.1 Built-up roof cladding

### Liner sheet

The liner sheet is the first component of the built-up roof to be installed and serves several purposes:

- It supports the thermal insulation
- It provides an airtight layer
- It provides restraint to the purlins.

Liner sheets are usually cold formed from pre-coated steel or aluminium and possess a shallow trapezoidal profile as shown in Figure 2.2. The dimensions of the profile vary from manufacturer to manufacturer, but a typical depth is 17 mm to 20 mm and a typical pitch (the distance between adjacent troughs) lies in the range 100 mm to 333 mm. For steel liners, the sheet thickness is usually either 0.4 mm or 0.7 mm, while aluminium liner sheets are slightly thicker at 0.5 mm or 0.9 mm. A cover width of 900 mm to 1000 mm is typical.



**Figure 2.2** Liner profile examples

The choice of liner will depend on the required load/span capabilities, the method of working for the cladding installation process and the acoustic requirements of the cladding. The liner profiles shown in Figure 2.2 are designed for use with traditional steel purlins and are, therefore, suitable for spans of approximately 1.5 to 2.0 m (typical purlin spacing is 1.8 m).

A typical liner sheet with a depth of approximately 20 mm will not have sufficient strength or stiffness to support the weight of cladding operatives or their materials and equipment. However, deeper profiles made from thicker steel (e.g. 32 mm deep and 0.7 mm thick) may sometimes be used to provide a working platform for the cladding installation activities, provided that sufficient protection is provided at edges, penetrations and rooflights. Where this option is chosen, the method statement for the cladding installation must ensure that heavy point loads are avoided and that the safe working load for the liner is not exceeded. Safety issues relating to working on roofs, including the important issue of non-fragility, are discussed in Section 5.5.

Where required, the acoustic performance of the cladding, in particular its ability to absorb sound and minimise reverberation, may be enhanced by the use of a perforated liner sheet.

## ***Insulation***

The primary function of the insulation layer is to provide a barrier to the flow of heat between the interior of the building and the external environment. As such, it is often seen as the prime candidate for change when improvements to the thermal performance of the cladding are sought. In reality, as discussed throughout this publication, the insulation layer only provides part of the solution, since good thermal performance is dependent to a certain degree on all components of the system and, in particular, on their mutual interaction. This is recognised in Part L of the Building Regulations by the importance placed on air leakage and cold bridging and the emphasis on whole building modelling in the latest (2006) revision of the Regulations. The thickness of the insulation layer in roof and wall assemblies has increased significantly in recent years from approximately 80 mm in the 1980s to values approaching 200 mm in 2006.

The most common form of insulation in built-up cladding systems is mineral wool quilt, which is favoured due to its light weight, low thermal conductivity, ease of handling and relatively low cost. It is usually supplied to site in tightly compressed rolls, making it easy to transport and store, but when unrolled, it expands to its required thickness and fills the void between the liner and the weather sheet. Where a bar and bracket spacer system is used, the insulation should be tucked under the bars, with all quilt edges tightly butted. The insulation is sufficiently soft to deform around the small profiled ribs on the liner and around the spacer system, thereby providing a continuous layer of insulation, as required by the Building Regulations.

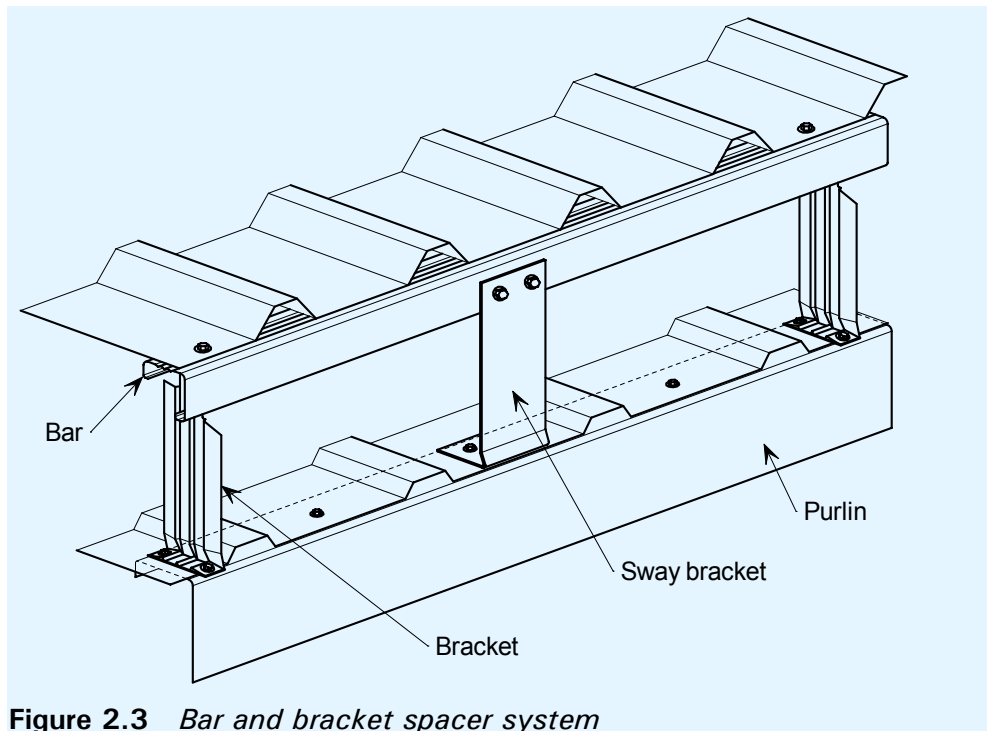
Rigid mineral wool slabs are available, but are less deformable than mineral wool quilts, giving rise to the potential for air gaps between the insulation and the profiled metal sheets. Care must be taken to avoid such gaps, as these could have a significant detrimental effect on the thermal performance of the building envelope. Rigid mineral wool slabs are also much heavier than mineral wool quilts, with consequences for the loading on the supporting steelwork and manual handling on site. However, slabs are sometimes specified in buildings that require an extended period of fire resistance.

## ***Spacer system***

The primary function of the spacer system is to support the weather sheet at the required spacing from the liner sheet. The components of the system must, therefore, possess sufficient strength and stiffness to safely transmit the required loading through to the purlins, without excessive deformation. In order to provide a safe and direct load path into the structural frame, the spacers should always be positioned over the purlins or other structural members and must be fixed securely to them.

The most common forms of spacer used in the UK are bar and bracket systems. These consist of cold formed steel bars, which provide continuous support to the weather sheet, supported at intervals by steel brackets firmly attached to the purlins through the liner. Many bar and bracket systems also incorporate plastic pads (which act as thermal breaks) in order to minimise thermal bridging. Other types of spacer system are also available, for example Z spacers supported on thermally insulating plastic blocks. Specifiers are advised to consult the manufacturers' literature for further details.

A typical bar and bracket spacer system is shown in Figure 2.3.



**Figure 2.3** *Bar and bracket spacer system*

Spacer systems are structural components through which the majority of externally applied loads (snow, wind etc.) are transmitted. It is important that this point is recognised by the specifier and that the structural adequacy of the system is checked at some point during the design process. This should be a straightforward matter, since structural data is available from the manufacturers and the loading requirements will be known by the structural engineer. However, for these checks to be carried out in practice, somebody within the design team must be given the responsibility for the task.

Consideration should also be given to the loading of the spacer system during the construction phase. This is especially important if the cladding contractor intends to load bundles of weather sheets onto the spacer system, since concentrated loads such as this can sometimes cause damage to the bar and brackets. A particular issue for designers and contractors to be aware of is the possibility of sway failure of the brackets as materials are placed on the bars. In some instances, the spacer system manufacturers recommend the use of 'sway brackets' to prevent this mode of failure. Further guidance should be sought from the individual spacer system manufacturers, as the recommendations tend to be product specific.

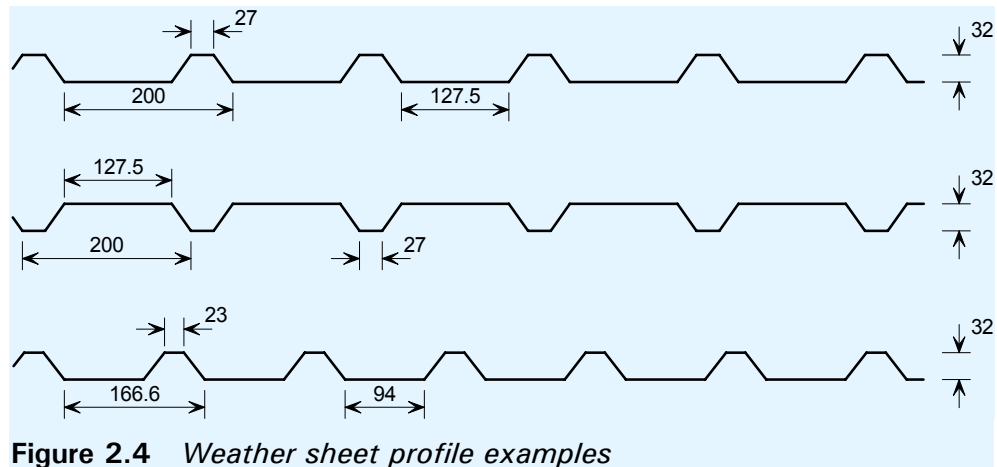
### ***Weather sheet***

The outer sheet of a double skin built-up cladding system is known as the weather sheet. As the name suggests, its prime function 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 an important role in transferring externally applied load (e.g. from wind, snow and foot traffic) through to the other cladding components, secondary steelwork and primary load-bearing frame.

In order to carry the applied loading from the wind or snow without excessive deflections, it is necessary for the weather sheet to possess adequate bending stiffness. This is achieved by rolling a profile into the sheet. The profile may either be trapezoidal, as shown in Figure 2.4, or sinusoidal. The depth and



pitch of the profile will vary, depending on the cladding product, but 32 mm is a typical depth for weather sheets (c.f. 20 mm for liners).



**Figure 2.4** *Weather sheet profile examples*

Note: Some roofing contractors choose to use weather sheet profiles as liner sheets in order to aid the installation of the liner (see Section 5.5.3).

The weather sheets are usually made from either steel or aluminium and are available in a wide variety of finishes and colours. Steel weather sheets are manufactured from pre-coated steel coil. The coating is made up of a series of layers comprising a metallic coating (e.g. galvanizing), 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:

- Plastisol
- Polyester
- Polyurethane
- Polyvinylidene Fluoride.

Aluminium weather sheets are available in a mill finish or in a range of painted finishes. The following materials are generally used:

- ARS
- Polyester
- Polyvinylidene Fluoride.

### ***Fasteners***

Specifiers can choose from a wide variety of proprietary fasteners and should refer to the manufacturers' literature for the full range of available products. Most of the fasteners used for metal cladding applications are self-tapping and self-drilling, although self-tapping only screws are also available. For most fastener applications, specifiers have the choice of plated carbon steel or stainless steel (typically grade 304 austenitic stainless steel is used). Visible fasteners have the option of factory coloured plastic heads to suit the weather sheet.

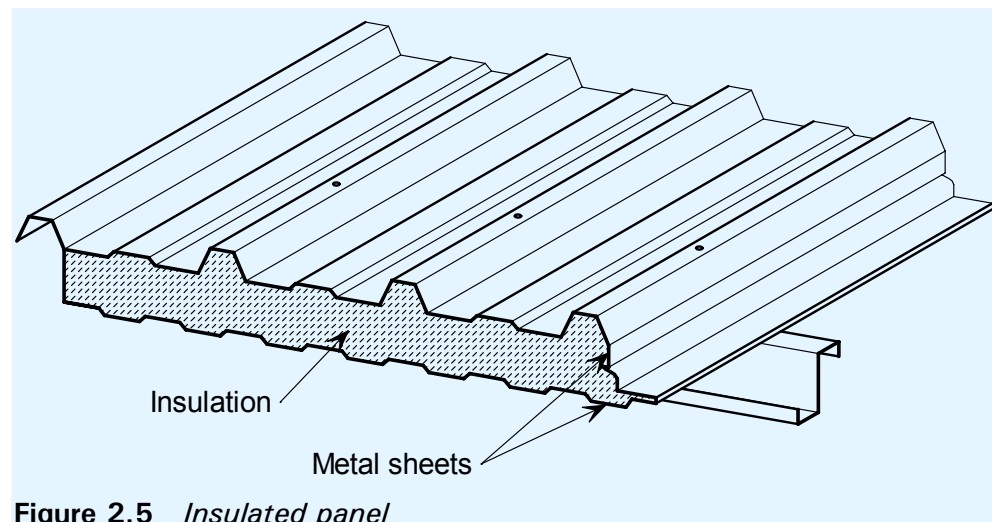
Fasteners can generally be divided into two categories: primary and secondary. Primary fasteners transfer the loads from the cladding to the supporting purlins and side rails. Their main function is therefore structural. Secondary fasteners

are used to form the joints between adjacent sheets (e.g. side lap stitcher fasteners) and between sheets and flashings. While their primary purpose is to provide a weathertight seal at the joint, their structural properties may be used to provide lateral restraint and to transfer load through diaphragm action.

Further information on fasteners is given in MCRMA Technical Paper No. 12 *Fasteners for metal roof and wall cladding: design, detailing and installation guide*<sup>[5]</sup>.

### 2.1.2 Insulated panels

Insulated roof and wall cladding panels consist of a rigid layer of insulation sandwiched between two metal skins. The result is a strong, stiff, lightweight panel with low thermal conductivity. By combining the liner, insulation and weather sheet into a single manufactured unit, the time required to install the cladding on site is significantly reduced. A typical insulated panel is shown in Figure 2.5.



**Figure 2.5** *Insulated panel*

Unlike built-up systems, there is no need for a spacer system, as the rigid insulation is strong and stiff enough to maintain the thickness of the panel. Any loads that are applied in the plane of the cladding (e.g. down-slope loads on a pitched roof) are transferred from the external sheet through the two adhesive bonds and the layer of insulation to the internal sheet and the supporting structure.

Polyisocyanurate (PIR) is the most common insulation material used in insulated panels. PIR expands rapidly when sprayed onto the metal profile and bonds to it without the need for an adhesive. This property makes it ideally suited to the type of continuous manufacturing process employed by the larger manufacturers of insulated panels. Alternatively, rigid slabs of mineral wool or other insulating materials may be bonded to the metal sheets using an adhesive.

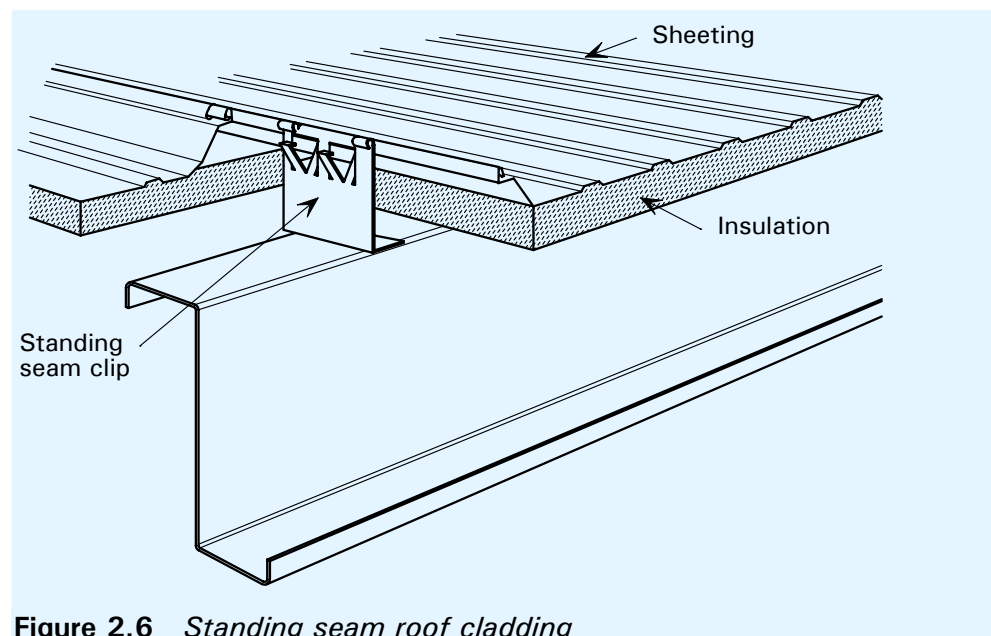
The inner and facing sheets used in insulated panels are similar to the liner and weather sheets used in built-up systems, except that the profile shape is less important in terms of panel strength and stiffness, due to the composite action between the two skins and the insulation layer. The profiles used in insulated panels are generally thinner gauge than those used in built-up systems and, especially for walls, tend to have shallower ribs (microribbed). Some insulated wall panels use a flat weather sheet, especially where there are specific aesthetic requirements (see Section 2.3). Steel is the most commonly used facing

material and is available in a variety of colours. Aluminium facings are occasionally used for specific projects. In the larger manufacturing facilities, the steel is delivered in pre-coated coils and the profiles are rolled as part of the same continuous process that inserts the insulation and saws the finished panels to length.

### 2.1.3 Standing seam systems

‘Standing seam’ or ‘secret fix’ systems use a specially designed profile for the weather sheet, which incorporates a clipped joint between adjacent sheets. This eliminates the need for exposed through fasteners and improves the weathertightness of the cladding system. Consequently, standing seam systems may be used on very low roof slopes (down to 1° compared to 4° for systems with exposed fasteners). Insulated panel systems are also available with a standing seam joint in the weather sheet.

A typical standing seam system is shown in Figure 2.6.



**Figure 2.6** *Standing seam roof cladding*

Further information on standing seam cladding systems may be obtained from MCRMA Technical Paper 3 *Secret fix roofing design guide*<sup>[6]</sup>.

## 2.2 Weathertightness

The primary function of the cladding system is to provide a weathertight building envelope, suitable for the intended use of the building. With this in mind, the cladding specifier must give careful consideration to the selection of the cladding components and the detailed design of the system. The location of the building, its orientation and the external climate should all be considered when specifying the cladding. The satisfactory performance of the system also depends on the correct assembly of the components in the factory and/or on site, as discussed in Sections 4 and 5 of this publication.

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. **Not all types of roof cladding are suitable for use on low pitch roofs. Specifiers must, therefore, pay careful attention to the minimum pitch recommended by the manufacturers, together with the published guidance on detailing and installation.**

Trapezoidal metal roof sheets with through fix fasteners are generally suitable for slopes of 4° or steeper. This 4° limit is critical to the performance of the cladding and should take into account deflections in the supporting steelwork and localised cladding deformations that may lead to ponding. Where the primary steelwork is precambered to off-set the dead load deflections, great care must be taken to ensure that excessive precamber does not result in local high points, as these could also cause ponding. For shallower pitches, down to 1°, a secret fix system with no exposed through fasteners, special side laps and preferably no end laps should be used. Secret fix systems may also be used on steeper roofs where increased reliability is desired.

For low pitch roofs, ponding is a potential problem that must be considered at the design stage in order to avoid the deleterious effects of prolonged soaking and the increased loading due to the weight of the water. Where ponding occurs on rooflights, there is also the additional problem of the water leaving dirt deposits as it evaporates.

**Side and end laps in profiled sheeting are weak points in the building envelope, where the wind and rain could potentially penetrate the cladding. The design and construction of the laps is therefore critical to the weathertightness of the cladding system.** End laps typically consist of two continuous butyl sealant strips, which are compressed to form a weathertight seal by the clamping action of the fasteners. The pitch of fasteners required to achieve a proper seal will depend on the profile geometry, but one fastener per trough is common. A typical side lap between trapezoidal sheets is formed by overlapping the profiles with a strip of butyl sealant positioned on the weather side of the fastener to provide a weather-resistant seal. The side laps should be stitched at 500 mm centres or closer using steel stitcher fasteners. Further information on side and end lap details is given in MCRMA Technical Paper No. 6 *Profiled metal roofing design guide*<sup>[7]</sup> and Technical Paper No. 16 *Guidance for the effective sealing of end lap details in metal roofing constructions*<sup>[8]</sup>.

## 2.3 Building appearance

The choice of wall and roof cladding can have a significant impact on the appearance of a building. The following factors are particularly important:

- Profile shape
- Colour
- Fasteners

The profile shape can have a significant impact on the appearance of a building due to its effect on the perceived colour and texture of the cladding (caused by the reflection of light). The orientation of the cladding (ribs horizontal or ribs

vertical) will also influence the appearance of the building, due to the effects of shadow and reflection. A potential disadvantage of horizontal ribs is that they tend to suffer from an accumulation of dirt over time, unless the cladding is cleaned regularly. Where the location and function of the building demand a smooth flat exterior, insulated wall panels with flat facing sheets may be used.

The steel from which profiled cladding sheets are made is available pre-coated in a wide range of colours and textures, allowing architects to choose a finish that best suits the location and function of the building (see Figure 2.7). **In choosing the finish, the architect should bear in mind the influence of the profile shape on the overall appearance by making an allowance for the effects of reflection and shadow on the perceived shade of colour.**



**Figure 2.7** *Gazeley G-Park Bedford using Corus Colorcoat Prisma®.*  
(Image courtesy of Corus)

The overall appearance of the building can also be affected by the choice of fasteners, especially on wall cladding or on steeply pitched roofs. Cladding specifiers should, therefore, give careful consideration to the size, shape, colour and locations of the fasteners and washers. Fasteners with factory coloured plastic heads are available to match the colour of the weather sheet. Where exposed fasteners are considered detrimental to the appearance of the building, the architect may consider the use of secret fix insulated panels or standing seam systems in which all fasteners are hidden from view.

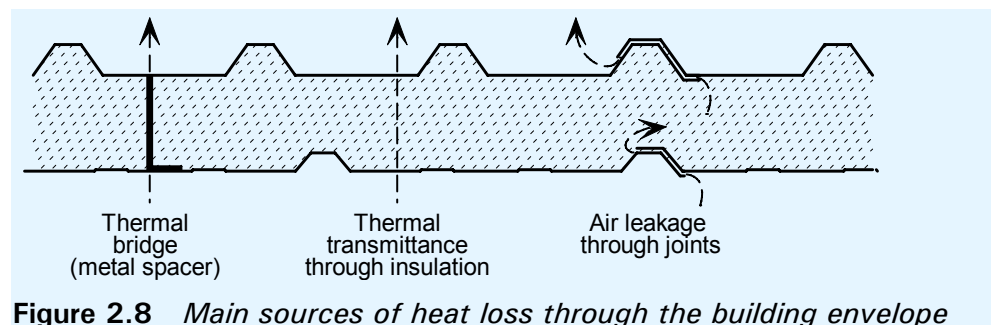
## **2.4 Thermal performance**

### ***Background***

The increase in public awareness of global climate change and the association with human activity has placed energy consumption and carbon dioxide emissions high on the political agenda. Under the terms of the Kyoto Protocol, the United Kingdom is now legally bound to reduce its carbon dioxide emissions and meeting this obligation will require significant changes in many sectors of industry, especially construction. The strategy for meeting the requirements of the Kyoto Protocol in the UK is set out in The Energy White Paper: *Our energy future: creating a low carbon economy*<sup>[9]</sup>.

A significant proportion of carbon dioxide emissions in the UK and 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*<sup>[10]</sup> and, in England and Wales, by Part L of the Building Regulations<sup>[1]</sup>. Although many factors influence a building's energy efficiency, the thermal performance of the building envelope is significant. Consequently, successive revisions of the Building Regulations have 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 2.8.



**Figure 2.8** Main sources of heat loss through the building envelope

### **The Building Regulations**

In the past, compliance with Part L of the Building Regulations has been defined in the corresponding Approved Documents in terms of the thermal transmittance (*U value*) and air leakage of individual building elements. Limiting values for both parameters were given in the Approved Documents. Traditionally, *U values* were seen as the primary means of improving thermal performance, resulting in a gradual increase in insulation thickness over several years to meet the ever stricter requirements. Limits on air leakage were also included in the Approved Documents, but were not strictly enforced in practice.

The recent (2006) revision of Approved Document L2<sup>[1]</sup> differs from the previous approach in that building designers are required to demonstrate an improvement in energy performance compared with the requirements of the 2002 Regulations, but they are given the freedom to choose how to achieve this improvement. The energy performance is quantified in terms of the CO<sub>2</sub> emissions associated with the operational energy requirements of the building. The energy requirements are a function of many aspects of the building design, such as the detailed design of the cladding, the availability of natural light and the type and efficiency of building services installed. For naturally ventilated buildings, the required reduction in CO<sub>2</sub> emissions is 23.5%, whereas mechanically ventilated or air conditioned buildings must achieve a 28% reduction compared with the 2002 notional building.

Unlike its predecessor, Part L 2006 considers the performance of the whole building, rather than the thermal properties of the individual elements of the building envelope. It is, therefore, no longer sufficient to specify cladding components or even whole systems based solely on manufacturers' published data. **Instead, compliance with the Regulations must be demonstrated using a whole building calculation model, such as the Simplified Building Energy Model (SBEM).** Minimum performance criteria in terms of *U values* and air

leakage are still included in the Regulations (set at the 2002 limits), but compliance with these limits is no longer sufficient in itself.

### ***U values***

The “*U value*” of an element or system is a measure of the ease with which it permits the passage of heat; the smaller the *U value*, the less heat is transmitted. *U values* are usually quoted in W/m<sup>2</sup>K and may be obtained by advanced thermal modelling techniques or from laboratory testing using a calibrated hot box. 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, e.g. metal spacers.

Changes to the Building Regulations over recent years have significantly reduced the maximum permissible elemental *U values* (i.e. increased the minimum allowable insulation) 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 (see Section 3.6). Future regulatory changes will inevitably continue the trend towards improved thermal efficiency. **However, the adoption of whole building modelling, together with the diminishing returns obtained from further reductions in *U values*, mean that more emphasis in future is likely to be placed on airtightness and the performance of mechanical services, rather than ever increasing insulation thicknesses.**

### ***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.

### ***Airtightness***

The airtightness of a building is central to the requirements of Approved Document L2 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. Approved Document L2: 2006 specifies a maximum permissible air permeability of 10m<sup>3</sup>/h/m<sup>2</sup> at a pressure of 50Pa (the same as the 2002 Regulations). However, in order to achieve the necessary reduction in CO<sub>2</sub> emissions, a significant reduction in leakage rate below this level is likely to be needed in practice.

There are many potential sources of air leakage in a building, for example poorly-fitting window frames or badly-detailed service penetrations, but this does not in any way diminish the importance of correctly specifying and

installing the roof and wall cladding. Laboratory tests have demonstrated the ability of profiled metal cladding to provide a high degree of airtightness when properly detailed and installed, but industry experience suggests that such high standards are not always achieved in practice.

### **Further information**

Detailed guidance on the thermal performance of building envelopes is given in *Guidance for the design of metal roofing and cladding to comply with Approved Document L2<sup>[11]</sup>* published jointly by MCRMA and EPIC.

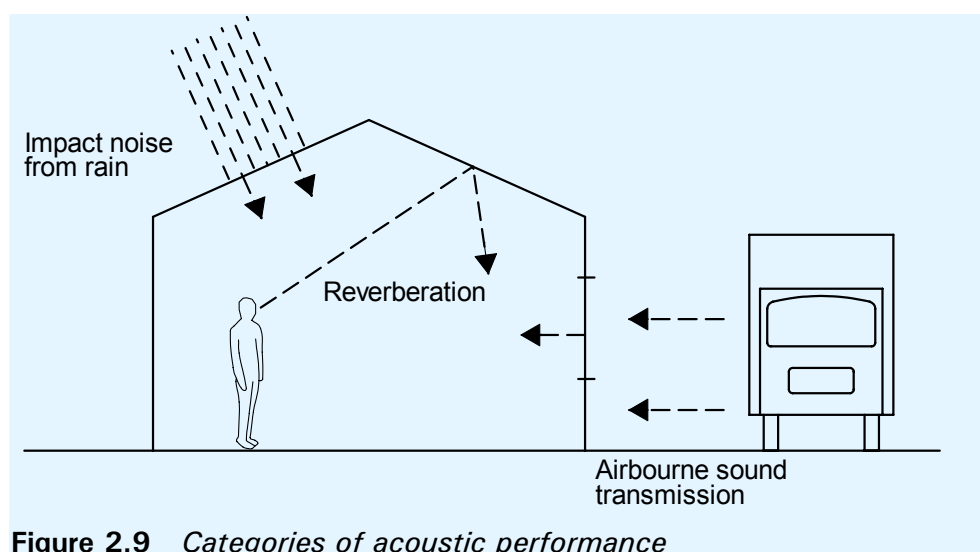
## **2.5 Interstitial condensation**

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 carbon steel components within the roof assembly or in wetting of the insulation.

Recommendations for avoiding interstitial condensation are given in BS 5250:2002 *Code of practice for control of condensation in buildings<sup>[12]</sup>*.

## **2.6 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 2.9.



**Figure 2.9** *Categories of acoustic performance*

### **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).

### ***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 profiled liner sheet with a perforated liner.

### ***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.

### ***Further information***

Further guidance is available in MCRMA Technical paper No. 8 *Acoustic design guide for metal roof and wall cladding*<sup>[13]</sup>.

## **2.7 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.

As noted in Section 2.1.1, the sheet metal from which the profiled weather sheet is made is available in 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*<sup>[7]</sup>. 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 (which is typically 20 to 30 years). Such coatings can provide significant benefits to the client in terms of whole life costs and improved safety.

## 2.8 Performance in fire

The fire performance requirements differ fundamentally from those relating to thermal performance, durability, weathertightness and acoustics in that fire is an exceptional event, from which it is unlikely that the building will survive in a serviceable state. Indeed, the purpose of the Building Regulations with respect to fire is to ensure the Health and Safety of the occupants and people close to the building, rather than to preserve the building. Consequently, the provisions of Approved Document B<sup>[14]</sup> aim to provide a safe means of escape for building occupants, allow safe access for the Fire Brigade and prevent the spread of fire to a neighbouring property.

Roofs do not usually need to provide any period of fire resistance, but they must be designed to prevent the spread of fire. The ability of the internal surfaces of cladding sheets to prevent the spread of flame is determined by testing to BS 476-7:1997<sup>[15]</sup> and is expressed as a classification ranging from 1 to 4. Profiled liner sheets generally achieve Class 1, which is the best rating. The sheets will also typically achieve the highest performance in the BS 476 Fire Propagation test, giving them an overall designation of ‘Class 0’, the highest product performance classification for a lining material. (The revised Approved Document B makes reference to the Euroclasses that will supersede the British Standard classification system. The current ‘Class 0’ is equivalent to ‘Euroclass B’.) The external surface of the cladding must also demonstrate adequate resistance to the spread of fire. In this case, the relevant tests are prescribed in BS 476-3:2004<sup>[16]</sup>.

The manufacturers of cladding systems are required to subject their products to rigorous fire tests in order to secure approval from the building insurance organizations. These tests are in accordance with Loss Prevention Council LPS 1181<sup>[17]</sup> or Factory Mutual FMRC 4880/4471<sup>[18,19]</sup> tests and certification. Specifiers of cladding products should ensure that such approval has been granted for the product under consideration and that it is deemed suitable for the application in question.

## 2.9 Structural performance

Profiled metal cladding systems not only provide a weather-tight envelope, but also serve as an important structural element. Typically, they are required to carry externally applied loads, such as snow and wind loading, over spans of up to 2 m, without deflecting excessively or compromising the other performance requirements. In addition, the cladding is often required to provide restraint to the purlins and side rails.

The following issues are considered in detail in this section:

- Loads

- Load combinations
- Deflections
- Use of safe load tables
- Load paths
- Purlin and side rail restraint
- Stressed skin construction.

### 2.9.1 Loads

#### *Dead load*

In most normal commercial and industrial applications, the only dead load for which the 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 2.1. For information on specific cladding products, designers are advised to consult the technical literature available from manufacturers or suppliers.

**Table 2.1** *Typical cladding system weights*

System	Insulation	Depth*	Sheet thickness		Weight kN/m <sup>2</sup>
			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 2.1 correspond to a U value of 0.25 W/m<sup>2</sup>K for typical cladding systems using the insulation shown.

For system depths other than those given in Table 2.1, the cladding system weight may be estimated by modifying the above values according to the insulation densities given in Table 2.2.

**Table 2.2** *Typical insulation densities*

Insulation type	Typical density (kg/m <sup>3</sup> )
Glass mineral wool	13-16
Stone mineral wool	27
Rigid polyisocyanurate (PIR)	40

#### *Imposed load in service*

BS 6399-3:1988<sup>[20]</sup> defines six types of imposed roof load as listed below (see also *Design of single-span steel portal frames to BS 5950-1:2000* (P252)<sup>[21]</sup>).

- A minimum distributed load of 0.6 kN/m<sup>2</sup> (on plan) for roof slopes less than 30°, where no access other than for cleaning and maintenance is provided.
- A concentrated load of 0.9 kN.

- A uniformly distributed load due to snow over the complete roof area. The value of the load depends on the building's location and height above sea level.
- Asymmetric snow load due to major redistribution of snow. This occurs when the wind transports snow from the windward to the leeward side of the roof. This load condition only applies to roof pitches greater than 15° (see Clause 7.2.3.3 of BS 6399-3).
- Asymmetric snow load due to artificial redistribution of snow. This occurs as a result of excessive heat loss through a small section of the roof or manual clearance of the snow to maintain access (see Clause 4.5 of BS 6399-3). Generally, it is industry practice not to consider this type of loading except where specifically requested.
- Non-uniform loads caused by snow drifting in areas of obstruction or abrupt changes of height, such as parapet walls or walls of adjacent buildings. The magnitude of this loading can be much larger than the uniform snow loading, but is only applied over a localised area. Snow drifting is regarded by BS 6399-3 as an exceptional load and a reduced load factor of 1.05 may be used with this load for ULS design.

If the roof is required to provide access (other than for cleaning and maintenance), the appropriate imposed load should be obtained from Clause 4.2 of BS 6399-3.

### ***Wind load***

The wind load should be calculated according to the procedures presented in BS 6399-2:1997<sup>[22]</sup>, taking into account the geographic location of the site, the shape and size of the building and the shelter provided by other buildings. This calculation gives values for internal and external pressures from which the forces on the roof and wall elements may be obtained.

It is important to note that the external pressure will be different on each face of the building and will also vary along each face. In particular, the external pressure may vary considerably between the windward and leeward slopes of a pitched roof, with the leeward side experiencing uplift and the windward side experiencing a net downward force (depending on the pitch angle of the roof). Specifiers should ensure that any areas of high local wind uplift forces are identified and that, where necessary, additional fasteners are specified for these areas.

The internal pressure is dependent on the number and size of any openings and their orientation relative to the wind. Dominant openings are especially significant in this respect.

Further information on wind load calculations may be obtained from SCI publication P286, *Guide to evaluating design wind loads to BS 6399-2:1997*<sup>[23]</sup>. SCI Advisory Desk Note 273<sup>[24]</sup> gives recommendations for the wind loads to be considered when checking deflections.

### ***Imposed load during construction***

The Construction (Design and Management) Regulations<sup>[2]</sup> place a requirement on designers to consider the structural performance of all buildings and their components during construction. In this respect, the cladding is no different from any other element in the building (e.g. the beams and columns) and should

be checked to ensure that it is adequate under construction loads. These loads should include the weight of operatives working on the roof and the weight of stacked materials.

Where built-up cladding systems are used, it is not normally necessary for the liner sheet alone to carry construction loads. Indeed, traditional shallow liner profiles should not be walked on, as this is likely to cause damage and may place the operatives at risk of injury. If the cladding contractor wishes to use the liner as a means of access, the specifier should ensure that a deeper profile is specified, e.g. a 0.7 mm thick, 32 mm deep standard weather sheet profile. Where shallow (e.g. 19 mm) profiles are specified, it is essential that cladding operatives work from suitable access stagings spanning between the purlins, as discussed in Section 5.

An important consideration during construction is the fragility of the cladding. This is discussed in detail in Section 5.5.2.

### **2.9.2 Load combinations**

Clause 2.4.1.1 of BS 5950-1:2000<sup>[25]</sup> states that “The factored loads should be applied in the most unfavourable realistic combination for the part or effect under consideration”. Clauses 2.4.1.2 and 2.4.1.3 of BS 5950-1:2000 prescribe the combinations that should be considered (for buildings without and with cranes respectively) in terms of dead, imposed and wind loads. However, the words “realistic combination” are open to interpretation when determining which loads to include in these combinations. SCI Advisory Desk Note 277, *Load combinations for the design of low-rise buildings*<sup>[26]</sup>, gives detailed guidance on this subject and its principal recommendations are repeated below.

#### ***Serviceability limit state***

Deflections should be checked under the following combinations of unfactored loads:

- 100% of the imposed load, calculated as the greater of the snow load and the minimum roof (maintenance) load (e.g. 0.6 kN/m<sup>2</sup>)
- 100% of the wind load
- 80% snow load + 80% wind load
- Other reasonable combinations that may arise from real and definable loads.

#### ***Ultimate limit state***

The resistance of the building elements should be checked under the following combinations of factored loads:

- Load combination 1: Dead load and imposed load (gravity load). In this case, the roof imposed load should be taken as the greater of the snow load and the minimum roof (maintenance) load (e.g. 0.6 kN/m<sup>2</sup>).
- Load combination 2: Dead load and wind load.
- Load combination 3: Dead load, imposed load and wind load. In this case, the roof imposed load should be taken as the snow load and/or other real and definable loads, but not the minimum roof (maintenance) load (e.g. 0.6 kN/m<sup>2</sup>).

### **2.9.3 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 should be calculated for the load combinations listed in Section 2.9.2 above under the action of unfactored serviceability loads. Construction loads are not normally included in the serviceability loads and deflections under these loads do not, therefore, need to be 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.

BS 5427-1:1996<sup>[4]</sup> provides recommended deflection limits for profiled metal sheeting under serviceability loads. Specifiers should note that these values are merely suggested limits for typical applications. Specific circumstances may dictate the need for lower limits. Where insulated panels or other proprietary cladding systems are used, specifiers should consult the manufacturer's technical guidance for the product under consideration.

### **2.9.4 Use of safe load tables**

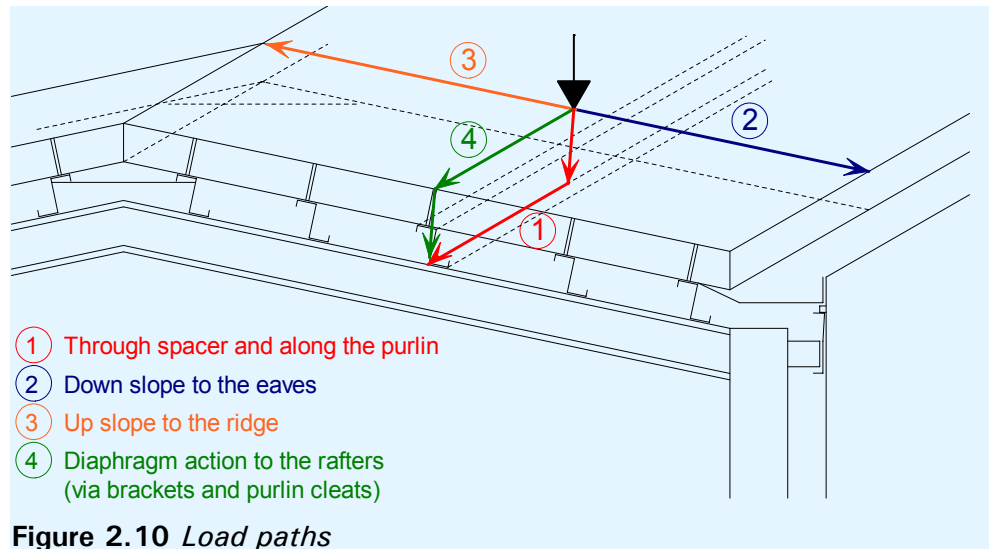
The manufacturers of profiled metal sheeting and insulated panels provide safe load tables for their products, which may be used either to select a suitable profile or, where the profile has already been chosen, to determine the maximum permissible purlin spacing. It is important to note that the load tables often assume that the loading is uniformly distributed. Additional design checks might be required to determine the performance of the cladding under concentrated point loads in excess of the 0.9 kN in BS 6399. Designers are advised to seek further guidance from the cladding manufacturers.

### **2.9.5 Load paths**

As part of the design process, it is essential that the structural engineer gives careful consideration to the load path (or paths) between the cladding sheets and the primary structural steelwork. This is especially important for built-up roof cladding carrying down-slope loads and built-up wall cladding supporting vertical loads.

In the case of built-up roof cladding, there are four potential load paths as shown in Figure 2.10:

1. Through the spacer system to the purlins and then back to the rafters;
2. Through the outer sheet down the slope to the eaves;
3. Through the outer sheet up the slope to the ridge;
4. In diaphragm action through the outer sheet and then via the spacer brackets to the rafters.



**Figure 2.10** *Load paths*

The down-slope load is distributed according to the relative stiffness of each load path. Load path 3 in Figure 2.10 is particularly stiff (due to the cladding being in tension), but its ability to carry load will depend on the detail at the ridge. Designers wishing to utilize this load path must ensure that sufficient fasteners are provided together with a suitable tie rod between the ridge purlins. The ability of the cladding system to transfer load by diaphragm action (load path 4) is dependent on the type of cladding, the number of seam fasteners, the presence of roof lights and the existence of a suitable edge detail to permit load transfer into the rafters. The proportion of load taken through the spacer system (load path 1) will depend on the stiffness of the spacer system relative to that of the other three load paths. It is likely that the relative stiffness of this load path has reduced in recent years owing to the increase in insulation thickness, but available test evidence indicates that it is still a viable load path.

### 2.9.6 Purlin and side rail restraint

It is common for the manufacturers of purlins and side rails to assume that their products receive a certain amount of restraint from the cladding panels or sheets. Indeed, the validity of the values in the manufacturers' safe load tables often depends on this assumption being realised in practice. **It is, therefore, important for the cladding specifier to ensure that the chosen cladding system is capable of providing the required degree of restraint and that it is appropriately detailed.** Alternatively, where the choice of a non-restraining cladding type is dictated by other factors (e.g. the use of a perforated liner for acoustic reasons), this fact should be communicated to the purlin and side rail specifier, in order to ensure consistency and safety throughout the design of the building.

The ability of a particular cladding profile to provide lateral and torsional restraint will depend on its strength and stiffness. These properties will in turn depend on the gauge of the steel or aluminium, the geometry of the profile and the number and spacing of the fasteners. The required restraining force will depend on the geometry of the purlin or side rail and the magnitude and nature of the loading that the member is required to carry. These issues are addressed in Section 3.6.

### 2.9.7 Stressed skin construction

It is sometimes possible to utilize the in-plane shear stiffness of the cladding to enhance the stability and sway stiffness of the primary steel frame. This is commonly referred to as stressed skin construction. Profiled metal cladding systems and insulated panels are especially suitable for this type of construction, provided that they are correctly detailed with sufficient fasteners. However, this approach is rarely adopted in practice for the following reasons:

- It is common practice for the structural engineer to design the steel frame before the architect specifies the cladding. This prevents the cladding stiffness from being incorporated into the structural model of the building.
- Stressed skin action requires a positive connection between adjacent sheets or panels, usually provided by the seam stitcher fasteners. Standing seam systems, which rely on friction, should not be used in stressed skin construction.
- Stressed skin action is severely disrupted by the presence of rooflights or openings in the cladding. Both are common in modern commercial and industrial buildings.

Where stressed skin construction is used, it is essential that the structural engineer and architect work closely together to ensure that a suitable cladding system is specified simultaneously with the design of the steel frame. Details of the design model and any assumptions on which it is based should be included in the project Health and Safety File, so that future owners of the building are aware of the structural function of the cladding. In some cases, it will be necessary to provide temporary bracing to stabilise the frame during construction. The main contractor and steelwork sub-contractor should both be made aware of this fact through the Health and Safety Plan.

Further information and design methods for stressed skin construction are given in BS 5950-9:1994<sup>[27]</sup>.



## 3 PURLINS AND SIDE RAILS

For steel 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 as shown in Figure 1.1. 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.

This Section presents guidance on the specification of light steel purlins and side rails. The following issues are considered in detail:

- Purlin and side rail options
- Loading
- Tolerances and deflections
- Purlin and side rail selection
- Rafter and column restraint
- Purlin and side rail restraint.

For flat roof applications, it is common to use deep structural decking profiles that span directly between the main structural frames, supporting a rigid layer of insulation and a waterproof outer membrane. This method of construction is outside the scope of this publication.

### 3.1 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.

#### 3.1.1 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 3.1. Further information may be obtained from the manufacturers' technical literature.

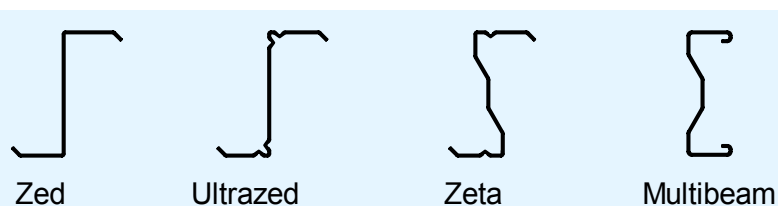
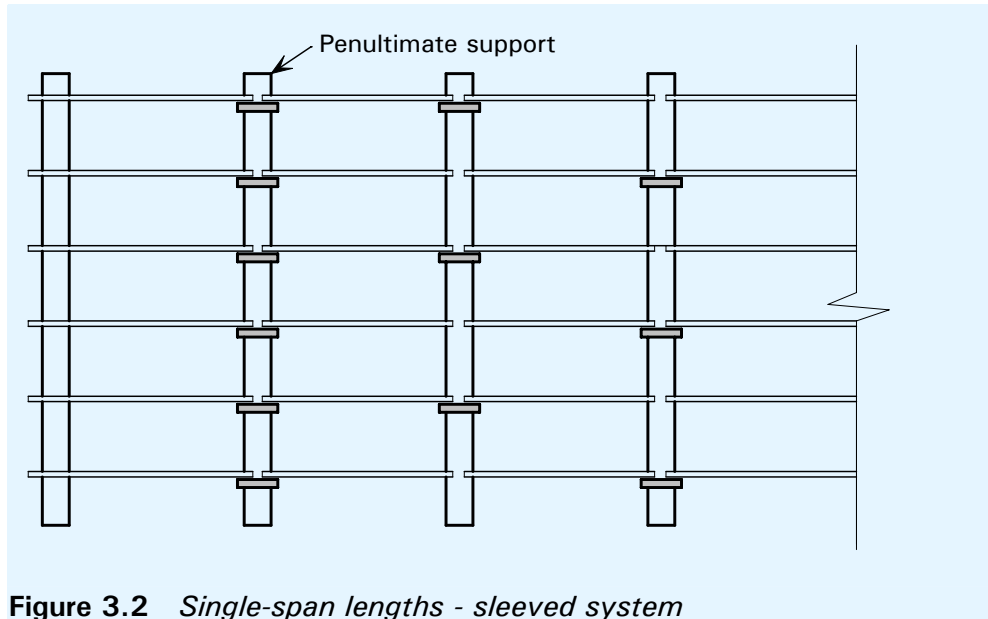


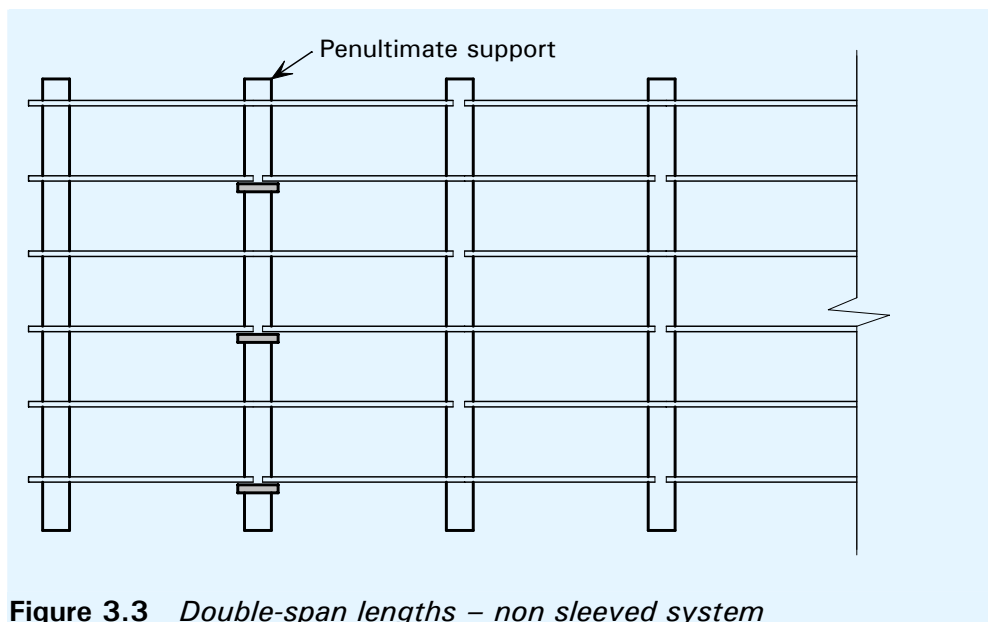
Figure 3.1 Common types of purlin

### 3.1.2 Purlin and side rail layout options

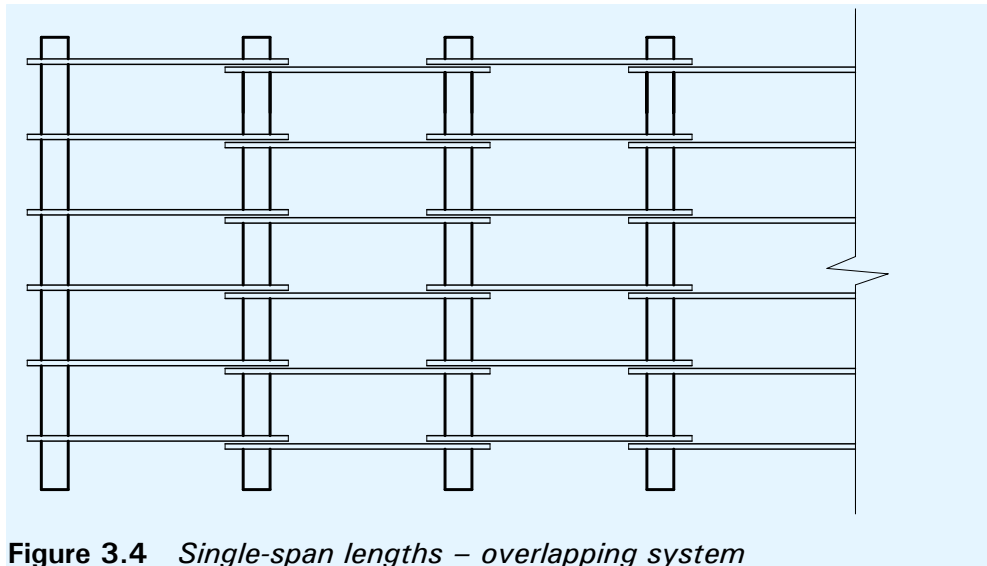
The most appropriate secondary steelwork layout for a particular application will depend on a number of issues, including the magnitude and distribution of the applied loads, the maximum available purlin/rail length (generally not more than 16 m for transport and handling reasons) and the shape and size of the building. Three of the most commonly used layouts are shown in Figure 3.2 to Figure 3.4. 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.



**Figure 3.2** *Single-span lengths - sleeved system*



**Figure 3.3** *Double-span lengths - non sleeved system*



**Figure 3.4** *Single-span lengths – overlapping system*

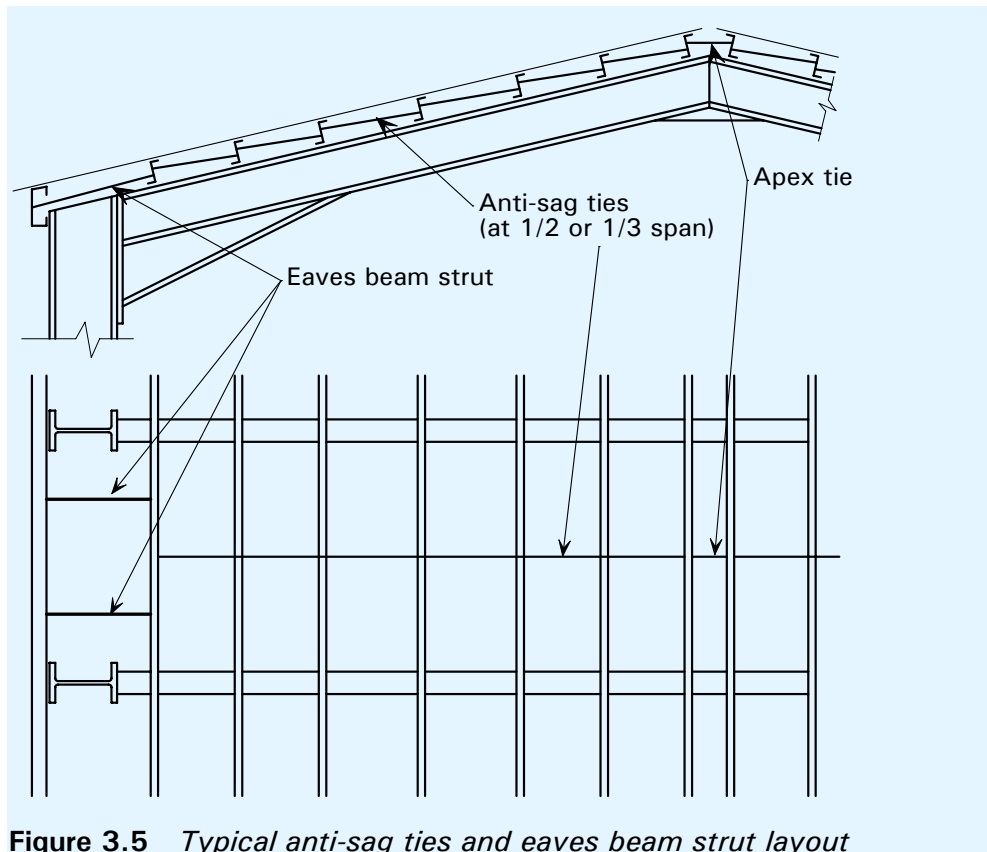
In the sleeved system shown in Figure 3.2, sleeves are placed on alternate purlins, making them effectively continuous across two spans. This arrangement is structurally more efficient than two single non-sleeved purlins. At the penultimate support, every purlin is sleeved to provide semi-continuity and additional strength in the end bay. Double-span systems, as shown in Figure 3.3, also provide continuity over two spans, but require the transport of long purlin lengths (12 m to 16 m). Where necessary, sleeves are provided at the penultimate supports to provide semi-continuity. As an alternative to the use of sleeves, purlins may be overlapped, as shown in Figure 3.4. Overlap purlins are supplied as single spanning lengths that extend either side of the rafters and are alternately inverted and overlapped to provide a continuous system suitable for long spanning applications.

### **3.1.3 The use of anti-sag rods**

Anti-sag rods are small rods or angles that are bolted or clipped between the purlins. A typical arrangement is shown in Figure 3.5; 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.
- They provide restraint to the purlins in the construction condition (before the installation of the cladding).
- They provide additional support to the down-slope component of the applied loads.
- They help to maintain the alignment of the purlins.

The anti-sag rods are assisted in these functions by eaves beam struts and apex ties, both of which are also illustrated in Figure 3.5.



**Figure 3.5** Typical anti-sag ties and eaves beam strut layout

The need for anti-sag rods is dependent on a number of factors, including the chosen purlin section, the spacing between the purlins, the span of the purlins and the magnitude of the applied loads. Advice on this issue may be obtained from the purlin manufacturers' technical literature. In some instances, the specifier may have a choice between the use of anti-sag rods or the selection of a heavier purlin that does not require intermediate restraint or support. There is clearly a trade-off between the cost of a heavier purlin section and the time (and corresponding cost) associated with the installation of additional components.

Note: Anti-sag rods only provide restraint at discrete locations along the span of the purlin. The purlins should only be considered to be 'fully' restrained under gravity loading in the finished condition, when continuous restraint is provided to the compression flange of the purlin by the cladding.

## 3.2 Loading

The purlins and side rails need to be designed to carry all of the loads applied to them from the cladding and to transfer these loads into the structural frame.

In the permanent state, these loads will include the factored dead, imposed and wind loads as described in Section 2.9.1. It will usually be acceptable to consider these loads as acting uniformly over the purlins, but account must be taken of high local forces such as the wind suction forces close to the end of a building.

In addition to the cladding loads, the purlins may also be required to support the weight of services or suspended ceilings. The structural engineer responsible for specifying the purlins will frequently play little or no part in the specification of the services or ceilings. Nevertheless, it is important that an

accurate estimate of these loads is obtained together with the nature of the loading (whether concentrated or distributed), since they could form a significant proportion of the overall gravity loading on the purlins. Particular care should be taken where the purlins are required to support concentrated loads.

Gutters and their supporting structure require special attention by the structural engineer, as the loads associated with them are often very high. Designers need to consider the dead load due to the weight of the gutters plus the imposed load due to their contents (water or snow). Specific information on the specified gutter system should be sought from the gutter manufacturers.

During the construction stage, the purlins may still be required to carry significant gravity loads, but without the benefit of any restraint provided by the cladding. The magnitude of the construction load will depend largely on the cladding installation procedure and the materials, plant and labour used. **The cladding installation sequence, in particular, can have a significant effect on the buckling resistance of a purlin, due to its influence on the unrestrained length of the purlin and the location of the load within the span. It is therefore essential that the designer takes account of the proposed method of working when specifying the purlins.** Preferably, this should be achieved by dialogue between the roofing contractor and the designer at the time of the purlin specification. In any event, the designer must ensure that all of the design assumptions on which the purlin selection was based are clearly noted in the Health and Safety Plan and Health and Safety File.

### **3.3 Deflections and tolerances**

#### **3.3.1 Deflections**

The deflection limits for the purlins and side rails are generally governed by the choice of roof and wall cladding, since the governing factor is the ability of the cladding to deflect without compromising weathertightness, airtightness, non-fragility or any of the other performance requirements described in Section 2. In general, the greater the flexibility of the cladding, the larger the allowable purlin or side-rail deflection. In this respect, profiled metal cladding systems are far more tolerant of deflections than brittle materials such as masonry. By contrast, windows are often critical and further guidance should be sought from the glazing manufacturers.

**Excessive deflection under purlin or rail self-weight, or under the action of construction loads prior to the fixing of the cladding, can lead to difficulties for the cladding installation.** This issue is discussed in Section 4.4.

Gutters are especially sensitive to deflections, due to the need to avoid drainage backfalls.

#### **3.3.2 Manufacturing tolerances**

The manufacturing tolerances for cold formed light steel sections tend to be small due to the high precision manufacturing technology used in their production. Indeed, the lightweight nature of the purlins and side rails means that any small out-of-straightness can often be corrected on site by the steelwork erectors, especially when anti-sag rods are used. Acceptable manufacturing tolerances for cold formed steel members are given in BS 5950-7:1992<sup>[28]</sup>,

including linear and angular dimensions over the cross section and along the length of the member.

### 3.3.3 Erection tolerances

**Improper or inaccurate erection of the purlins or side rails not only creates difficulties for the cladding contractors, but can also invalidate the assumptions underlying the cladding specification. In extreme cases, poor erection could compromise the integrity of the building envelope, leading to failure of the building air permeability test.** There are also health and safety implications for those working on the roof, especially during the installation of the roof cladding. It is, therefore, essential that the appropriate erection tolerances for the purlins, side-rails and any associated components are specified by the structural engineer responsible for the secondary steelwork and that these requirements are communicated in writing to the steelwork contractor. This issue is considered in detail in Section 4.4.

BS 5950-7:1992 includes some general guidance on dimensional tolerances for cold-formed steel members, but does not specifically consider purlins and side rails. However, The *National Structural Steelwork Specification* (NSSS)<sup>[29]</sup> is currently being revised and the new edition (5<sup>th</sup>) will include tolerances on the position and orientation of purlin cleats and other similar attachments. Further recommendations are given in Section 4 of this publication.

## 3.4 Purlin and side rail selection

The major purlin and side rail suppliers in the UK have invested heavily over many years in the development and testing of their systems and all publish design guidance and load/span tables for their products. In many cases, design software is also available. Several suppliers have had their systems and supporting technical data verified by the SCI through the Light Gauge Accreditation scheme, providing specifiers with added assurance regarding the correctness of the design models and accuracy of the load/span tables.

Thanks to these design tools, the structural engineer is spared the complexities of the design of light steel members and can simply select the most suitable section from the available range. However, specifiers should note that in using the load/span tables they are automatically accepting the assumptions made by the purlin and side rail manufacturers, including assumptions regarding the level of restraint provided by the cladding to the supporting steelwork (see Section 3.6). If in doubt, the secondary steelwork specifiers should contact the manufacturers for advice on the suitability of the chosen section for the application in question, taking into account the proposed cladding type and any other circumstances likely to invalidate the manufacturer's assumptions, e.g. heavy point loads.

## 3.5 Restraint provided to the rafters and columns

The structural efficiency of any steel framed building depends not only on the selection of light and efficient sections, but also on the interaction between the frame members, the secondary steelwork and the cladding system. For this reason, it is common practice in the United Kingdom for the structural engineer to assume a reasonable amount of lateral and torsional restraint when designing the primary steel frame. Of particular relevance to this publication is the

restraint provided to the rafters and columns by the purlins and side rails respectively.

BS 5950-1:2000<sup>[25]</sup> presents recommendations for lateral and torsional restraint. Clause 4.3.2.2.2 considers the required resistance for lateral restraints and states, “Where three or more intermediate lateral restraints are provided to a member, each intermediate lateral restraint should be capable of resisting a force of not less than 1% of the maximum value of the factored force in the compression flange within the relevant span.”

Clause 4.3.2.2.4 of BS 5950-1:2000 states that purlins need not be checked for forces arising from the lateral restraint of rafters in either roof trusses or portal frames provided that the following conditions are met:

- The purlins are adequately restrained by sheeting.
- There is bracing of adequate stiffness in the plane of the rafters or alternatively the roof sheeting is capable of acting as a stressed-skin diaphragm.
- The rafters carry predominantly roof loads.

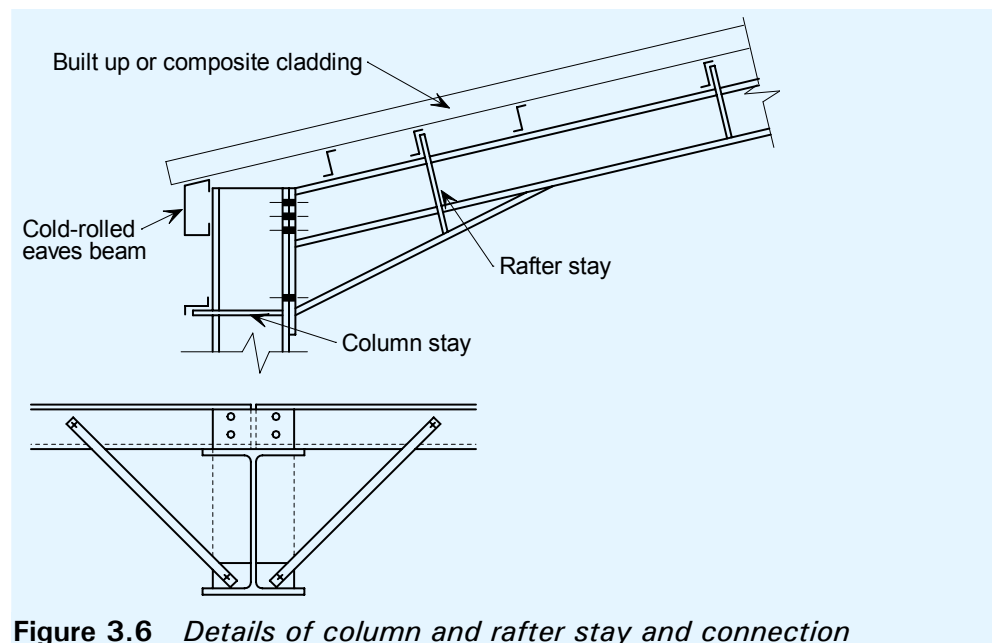
The first of these conditions is normally satisfied by the use of built-up cladding or insulated panels, as discussed in Section 3.6. The second condition is usually met by bracing in the plane of the roof, although stressed skin action may sometimes be employed, provided that the type of roof cladding is known at the time that the structural design is undertaken and that the cladding is capable of behaving as a diaphragm.

Within the context of Clause 4.3.2.2.4, the term “roof loading” refers to the usual dead and imposed loads that are applied to the rafters via the purlins. This loading includes most normal service loads, but excludes large concentrated loads that would require additional restraint. This approach ensures that, within reason, the purlin size is commensurate with that of the rafter it is restraining.

Ideally, the compression flange of the rafter or column should be laterally restrained by direct attachment of the purlins or side rails. However, under the action of wind uplift, or close to the haunches of a portal frame under gravity loading, the inner flange of the member (i.e. the one to which the cladding is not attached) will be in compression and cannot be restrained directly by the purlins or side rails. In this situation, the frame designer can either introduce an additional hot-rolled steel member (often a structural hollow section) to laterally restrain the compression flange or, alternatively, the compression flange can be effectively held in position by a combination of lateral restraint to the tension flange (provided by the purlins or rails) and torsional restraint provided by stays. Recommendations for the design of torsional restraints are given in Clause 4.3.3 of BS 5950-1:2000.

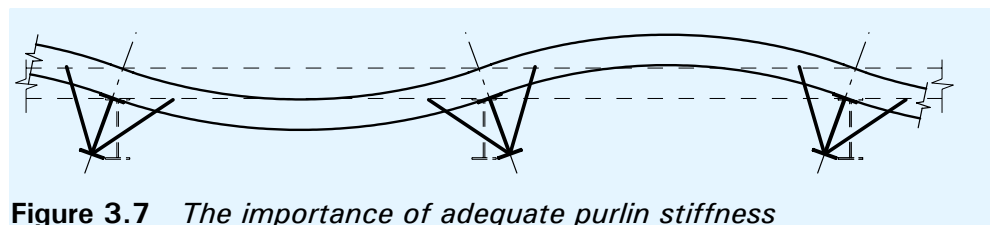
In the specific case of plastically designed portal frames, Clause 5.3.2 of BS 5950-1:2000 requires a torsional restraint at each plastic hinge location, designed to resist a force equal to 2.5% of the force in the compression flange at this location. This requirement does not apply to a plastic hinge that is “non-rotated” at ULS, because it is the last hinge to form or is not yet fully formed.

Rafter or column stays, as shown in Figure 3.6, may be used to provide torsional restraint to the rafter or column provided that they are connected to a suitably stiff purlin or side rail. Angles are commonly used as the stays. The stay and its connections should be designed to resist a force equal to 2.5% of the maximum force in the column or rafter compression flange between the adjacent restraints.



**Figure 3.6** Details of column and rafter stay and connection

In order to provide the required level of torsional restraint to the rafters or columns, the purlins or side rails must possess sufficient flexural stiffness. Otherwise, there is a risk that the restraining member will bend and allow the restrained members to rotate, as shown in Figure 3.7. As a rule of thumb, it is normally adequate to provide a purlin or side rail of at least 25% of the depth of the member being restrained. In practice, this generally means that the purlins and side rails will be sufficiently stiff for portal frames with spans up to 40 m and frame spacings of 6 to 8 m. However, as the span increases relative to the frame spacing (and the rafter size increases relative to that of the purlins), the purlin stiffness may become insufficient to provide adequate torsional restraint and should, therefore, be checked.



**Figure 3.7** The importance of adequate purlin stiffness

For spans greater than 40 m, the stiffness of the purlin or side rail may be considered to be sufficient to restrain the rafter or column if the following expression is satisfied (from Horne and Ajmani<sup>[30]</sup>):

$$\frac{I_s}{I_f} \geq \frac{f_y}{190 \times 10^3} \left( \frac{B(L_1 + L_2)}{L_1 L_2} \right)$$



where:

- $I_s$  is the second moment of area of purlin or side rail about its major axis
- $I_f$  is the second moment of area of the rafter or column about its major axis
- $f_y$  is the yield stress of the rafter or column (in  $\text{N/mm}^2$ )
- $B$  is the span of the purlin or side rail.

$L_1$  and  $L_2$  are the distances either side of the plastic hinge to the eaves, point of contraflexure, or column base, as appropriate.

## 3.6 Restraint of purlins and side rails

### 3.6.1 The need for restraint

Cold-formed steel purlins and side rails are extremely efficient at carrying loads by bending action, but they are susceptible to failure through lateral-torsional buckling unless they are adequately restrained. The economic and safe design of the cladding and its supporting steelwork relies on the interaction between the individual components that make up the whole system. In the case of roof cladding, these components include the purlins, cladding sheets, spacer system (where applicable) and fasteners.

Purlins and side rails are normally selected from manufacturer's load/span tables, which are derived from analytical models supported by test data. In producing their design data, all purlin manufacturers have to make a judgement regarding the degree of restraint that is available from the cladding system under gravity and wind uplift conditions. These assumptions are central to the design model and can have a significant effect on the design resistance of the purlin. **It is, therefore, essential that an equal or greater level of restraint is achieved in practice. This will depend on the choice of sheeting and the spacing of the fasteners.**

In addition to the continuous restraint provided by the cladding, restraint may also be provided at discrete intervals by anti-sag rods. These intermediate restraints limit the buckling length of the purlin, thereby increasing its resistance to bending loads. This is particularly useful in the wind uplift case, in which the purlins are only partially restrained by the cladding. The purlin manufacturers allow advantage to be taken of this restraint by including uplift capacities for one and two anti-sag rods in their design tables. However, there are cost and time implications associated with the use of anti-sag systems that might preclude their use in certain situations.

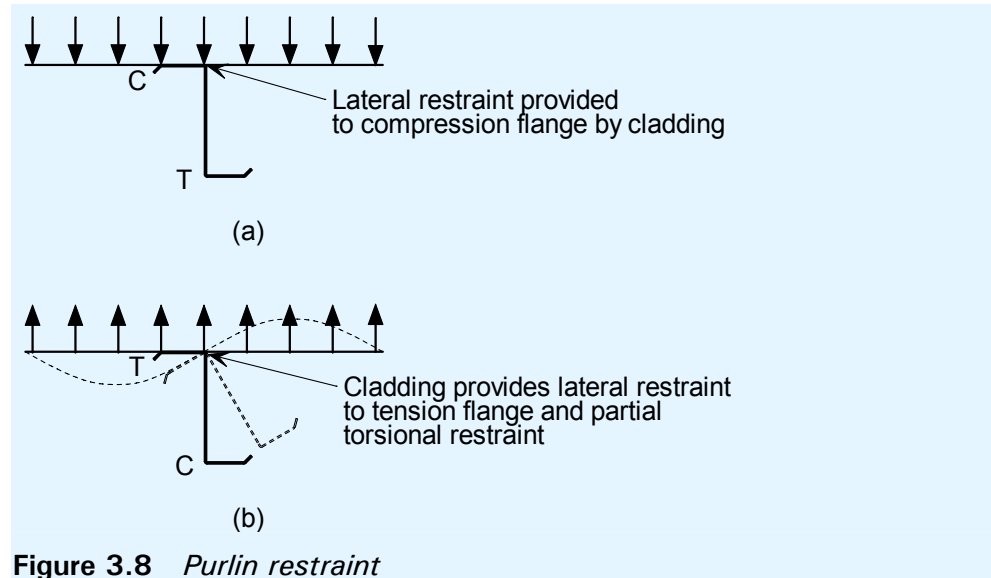
Note: The purlin resistance values for one or more anti-sag rods quoted in the manufacturers' load/span tables assume some restraint from the cladding in addition to the intermediate restraint provided by the anti-sag rods.

### 3.6.2 The ability of the cladding to provide restraint

#### *Lateral restraint – gravity case*

In the gravity load case (or positive wind pressure in the case of a wall), restraint is provided directly to the top flange of the purlin (or side rail) by the liner sheet or insulated panel, as shown in Figure 3.8(a). The ability of the cladding to provide the necessary restraint depends on its in-plane shear stiffness

relative to the stiffness of the purlin. For built-up systems, the shear stiffness is dependent on the number and size of fasteners, the dimensions of the liner profile and weather sheet, the overall depth of the cladding and the type of spacer system employed. Of these parameters, the stiffness of the liner and that of the connection to the purlin have the greatest influence on the degree of restraint provided. When insulated panels are used, designers need only consider the effect of the fasteners on the shear stiffness, as the panel itself can be assumed to be rigid in this instance. The shear stiffness of cladding sheets and panels may be calculated approximately using rules in Eurocode 3<sup>[31]</sup> (see Section 3.6.3), but it is normally determined by testing.



**Figure 3.8** *Purlin restraint*

**Tests and analysis to Eurocode 3 have shown that sufficient lateral restraint for the gravity load case is provided by conventional insulated panels (provided the number and strength of fixings is adequate) and non-perforated steel liners down to 0.4 mm thickness.** Aluminium liners might also provide adequate restraint if they are made from a suitable alloy and are at least 0.7 mm thick. The situation with perforated liners is not so straightforward, as their stiffness depends on the size and pattern of the perforations in addition to the material grade and sheet thickness. In general, perforated liners are not considered to be restraining and the supporting purlins should, therefore, be designed as unrestrained members.

#### ***Torsional restraint – wind uplift***

For wind uplift (or negative pressure on a wall), the cladding cannot provide lateral restraint directly to the compression flange. In this case, the purlin (or side rail) is restrained by a combination of lateral restraint to the tension flange and torsional restraint, as shown in Figure 3.8(b). The ability of the cladding to provide restraint is dependent not only on its in-plane shear stiffness (including the fasteners), but also its flexural stiffness. Inadequate cladding stiffness could lead to a similar problem to that illustrated in Figure 3.7 for the case of a purlin restraining a rafter.

Unlike the gravity load case, the cladding only provides partial restraint to the purlin, represented by the rotational spring stiffness  $C_D$  in Figure 3.9. The value of  $C_D$  will naturally depend on the details of the cladding system but, importantly, there is no specific value at which the cladding is deemed to provide full restraint. The matter is further complicated by the fact that varying

degrees of restraint (i.e. values of  $C_D$ ) are assumed by the different purlin manufacturers in their load/span tables, so it is impossible to give definitive guidance on which types of cladding provide adequate restraint and which do not. However, analyses and tests suggest that standard insulated panels and built-up cladding systems with a non-perforated steel liner sheet of at least 0.4 mm thickness will provide a similar magnitude of restraint to that assumed in the load/span tables, even at the increased cladding depths brought about the need for thicker insulation. **Purlin manufacturers give guidance on which types of cladding they consider to be adequate to restrain their purlin systems and this guidance should be followed carefully.**

### 3.6.3 The Eurocode 3 model

#### *Lateral restraint – gravity case*

Where trapezoidal sheeting is connected to the top flange of a purlin, Clause 10.1.1 of EN1993-1-3<sup>[31]</sup> states that the purlin may be regarded as being laterally restrained in the plane of the sheeting at the connection if:

$$S \geq \left( EI_w \frac{\pi^2}{L^2} + GI_t + EI_z \frac{\pi^2}{L^2} 0.25 h^2 \right) \frac{70}{h^2}$$

where:

- $S$  is the portion of the shear stiffness provided by the sheeting to the member under consideration
- $I_w$  is the warping constant of the purlin
- $I_t$  is the torsion constant of the purlin
- $I_z$  is the second moment of area of the purlin about its minor axis
- $L$  is the span of the purlin
- $h$  is the height of the purlin.

$S$  may be calculated by Equation 10.1b of EN 1993-1-3, which states that:

$$S = 1000 \sqrt{t^3} \left( 50 + 10 \sqrt[3]{b_{\text{roof}}} \right) \frac{s}{h_w} \text{ (N)}$$

where:

- $t$  is the sheet thickness (mm)
- $b_{\text{roof}}$  is the roof width (mm)
- $s$  is the purlin spacing (mm)
- $h_w$  is the profile depth (mm).

Equation 10.1b of EN 1993-1-3 is limited in the variables it considers (for example it does not take into account the number of fasteners). As an alternative means of calculating  $S$ , the procedures given in BS 5950-9<sup>[27]</sup> may be used to determine the shear flexibility  $c$  of a single panel between rafters (in mm/kN), from which  $S$  may be evaluated using the following formula:

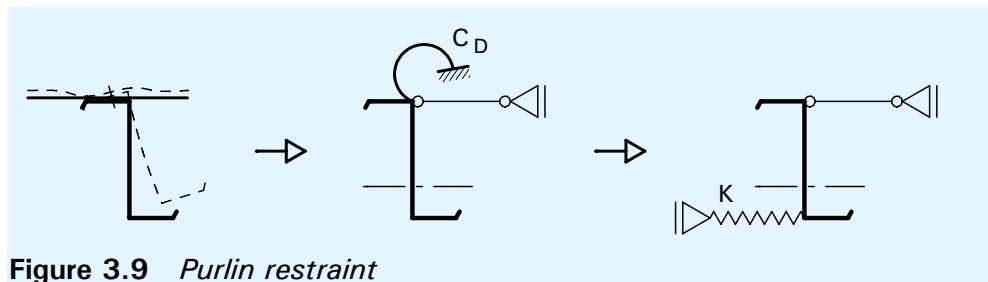
$$S = \frac{b}{Nc}$$

where:

- $b$  is the width of the panel (mm)
- $N$  is the number of purlins
- $c$  is the shear flexibility of a single panel between rafters (mm/kN).

### **Torsional restraint – wind uplift**

The torsional restraint provided to the purlin by the cladding is represented by a rotational spring of stiffness  $C_D$  located at the sheeting level, as shown in Figure 3.9. Restraint to the free flange is also provided by the resistance to distortion of the section itself. As a simplification, the effect of both types of restraint to the free flange is taken into account by a lateral spring of stiffness  $K$  located at the free flange level. A high value of  $K$  indicates a high degree of restraint.



**Figure 3.9** Purlin restraint

The rotational spring stiffness  $C_D$  depends on the connection between the top flange of the purlin and the sheeting, in addition to the flexural stiffness of the sheet itself. Although  $C_D$  is usually obtained through testing, an approximate calculation method is also presented in Eurocode 3 (EN1993-1-3 Clause 10.1.5.2).

The rotational spring stiffness  $C_D$  is given by

$$\frac{1}{C_D} = \frac{1}{C_{D,A}} + \frac{1}{C_{D,C}}$$

where:

- $C_{D,A}$  is due to the stiffness in the fixings
- $C_{D,C}$  is due to the bending stiffness of the liner.

It is worth noting that the flexibility of the fixings ( $C_{D,A}$ ) is normally significantly greater than that of the sheet ( $C_{D,C}$ ) and is therefore dominant, so accurate determination of the sheeting stiffness may not be necessary. A conservative method for calculating  $C_{D,C}$  is given in Clause 10.1.5.2(4)), while Clause 10.1.5.2(7) gives a simple formulation for  $C_{D,A}$  that may be applied provided certain geometrical constraints are satisfied. Alternative formulae are given in 10.1.5.2(5).

## 4 INSTALLATION OF PURLINS AND SIDE RAILS

### 4.1 Introduction

The ability of a steel framed building to perform adequately depends on good interaction between the secondary steelwork and the cladding. Crucial to this interaction is the correct installation of the purlins and side rails. This Section presents good practice guidance on the storage, handling and installation of the secondary steelwork and associated components. The two primary concerns are the health and safety of the site operatives (or anyone else on or close to the site) and fitness for purpose of the installed steelwork.

The guidance is primarily concerned with installation and other site-based activities and will, therefore, be of interest to supervisors, foremen and engineers from organizations involved in steelwork erection. However, there are several issues relating to the specification of the purlins and side rails that have a direct impact on their installation (e.g. achieving tolerances) and require the attention of the design team. These issues are also dealt with in this Section.

### 4.2 Handling and storage

The purlins and side rails are normally delivered to site on articulated lorries approximately 16 m long with a typical turning circle of 19 m. These vehicles will require suitable clear access onto the site (often an issue in congested urban locations) and appropriate standing and off-loading areas. Depending on the nature of the site and the size of the building, the logistics of this operation might require considerable planning to ensure that the steelwork is delivered to the correct location on the site without adversely affecting the other site operations. This planning and any associated groundworks are normally the responsibility of the main contractor. However, the steelwork contractor should ensure that the arrangements are suitable and convenient, taking into account the final destination of the steelwork on the building and the need to lift the materials to this location.

Before off-loading, the consignment should be checked against the accompanying documentation, which in turn should be checked against the drawings and the specification. Care should be taken to distinguish between similar components, for example members with the same depth made from different gauges of steel. To avoid confusion, all components should be tagged or clearly marked and, where possible, different sizes stored apart. (Ideally, the situation should be avoided at the design stage by specifying standard components, even if this means a small increase in the overall weight of steel). At this time, a visual inspection should be made to ensure that no damage has occurred during transit.

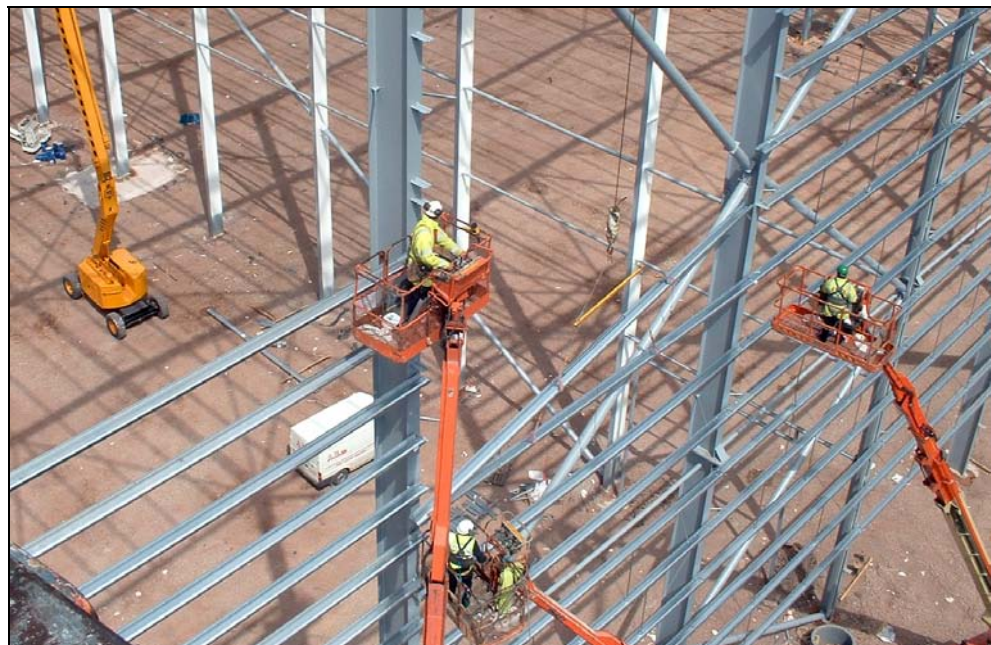
The purlins and side rails are normally unloaded by means of a crane. This lifting operation must be carried out in accordance with the appropriate safety regulations and should be supervised by a competent person. **To reduce the risk of damage during the lift, only protected chain slings or synthetic slings should be used. These should be positioned so as to provide adequate support and prevent excessive sag during the lift.** Lighter members may

sometimes be lifted by hand, but operatives should observe the recommendations of the Manual Handling Regulations to avoid injury. Under no circumstances should the purlins or rails be unloaded by tipping or dropping.

Whenever possible, the secondary steelwork should be delivered on a “just in time” basis. However, it is likely that there will be a requirement to store at least some of the components, even if only for a short duration. A suitable storage location should be found close to the final destination of the steel on the building, but clear of any access roads or other heavily trafficked areas where they might be at risk of damage from passing plant or vehicles. **All light gauge steelwork should be placed on wooden or concrete blocks to keep it clear of the ground and to allow slings to be removed without being damaged and attached again for future lifting.**

### 4.3 Installation

The purlins and side rails are normally installed by the steelwork contractor at the same time, or immediately after, the erection of the hot-rolled steel frame. The precise erection sequence will need to be determined by the steelwork contractor to suit the specific requirements of the building and fit in with the other construction activities. In determining the erection sequence, a governing factor will be the need to provide restraint to the rafters and columns, since the structure will not be capable of supporting its full design loading until the secondary steelwork has been fully installed. For this reason, it is not uncommon, especially on large buildings, for the secondary steelwork installation to begin before completion of the primary steelwork. The lack of restraint in the temporary condition must be taken into account when assessing the capability of the frame to carry construction loads.



**Figure 4.1** *Side rail installation.* (Image courtesy of Barrett Steel Buildings Ltd)

**The installation of the purlins and side rails should be performed from mobile access platforms (cherry pickers or scissor lifts) as shown in Figure 4.1, with the individual members being lifted into position by crane, either directly off the back of the delivery lorry or from their storage**

**location on the ground.** This method of working avoids the need to stack purlins on the unrestrained rafters and contributes to a safe system of work for the steelwork contractor's operatives. Any other roof components that require the use of mobile access platforms should also be installed at this time, because this means of access will be lost as soon as the safety nets are installed for the cladding operations. These nets will remain in place until the roof has achieved "non-fragile" status (see Section 5).

## 4.4 Erection tolerances for purlins and side rails

### 4.4.1 The need for accurate secondary steelwork

Crucial to the performance of the cladding system is the accurate installation of the purlins and side rails to the required tolerances. There is little available guidance on specific erection tolerances for secondary steelwork in the UK although more general tolerances for cold-formed steel members are given in Section 4.8 of BS 5950-7:1992<sup>[28]</sup>. In addition, the 5<sup>th</sup> Edition of the *National Structural Steelwork Specification* (NSSS)<sup>[29]</sup> will include erection tolerances for 'attachments', including the cleats used to attach the purlins and side rails to the rafters and columns respectively.

**The over-riding issue regarding erection tolerances for secondary steelwork is the ability of the cladding contractor to fix the cladding to the purlins and side rails, without compromising the airtightness, weathertightness or structural integrity of the building envelope.** There are also important health and safety implications for those working on the roof, since the non-fragility of the roof cladding (i.e. its ability to prevent a person from falling through the roof) is directly related to the quality of the supporting steelwork and the connections to it.

While the majority of secondary steelwork in the UK is erected to a high standard, roofing contractors have reported difficulties attaching the cladding on some buildings, due to the purlins or side rails being out of position or deformed. There are several possible reasons for these difficulties, including poor specification by the structural engineer and bad site practice on the part of the cladding contractor's operatives (e.g. walking on unrestrained purlins), so it would be unfair to blame every instance on poor erection. Nevertheless, the achievement of good secondary steelwork erection to reasonable tolerances is a logical and necessary step towards tackling this issue.

Two categories of problem have been identified:

- Deviations in the position and orientation of the cleats connecting the purlins and side rails to the primary steelwork.
- Deviations within the span of the purlins.

The first of these categories of problem is a steelwork fabrication issue and is dealt with by the *National Structural Steelwork Specification* 5<sup>th</sup> Edition and Section 4.4.2 of this publication. The most important requirement from the cladding contractor's point of view is being able to fasten the cladding to the purlin or rail. In this respect, some cladding contractors have commented that tolerances on the cleat position are less problematic than deviations in the purlin within the span. However, cleat orientation is extremely important, since a

small rotation in the purlin at the rafter can have a significant effect in its mid-span position.

The second category of problem refers to the in plane ‘sagging’ of the purlin or rail along its length at the time of the cladding installation. This is generally more serious than cleat position, as it prevents the cladding from being laid in a straight line between the columns or rafters and may result in the fasteners missing the purlins or rails into which they are supposed to fasten. Purlin sag is not necessarily a steelwork fabrication or erection issue (although cleat rotation is sometimes a contributory factor) and is, therefore, not covered by the NSSS. However, there is a responsibility on the part of all members of the project team to ensure that their activities (e.g. specification, fabrication, transport and handling, erection and use) do not contribute to the problem.

Suggested limits for purlin and side rail sag (i.e. positional accuracy at mid-span) are given in Section 4.4.3 of this publication. These values are based on industry best practice and have been shown to be achievable and to satisfy the requirements of typical built-up cladding systems and insulated panels. For other types of cladding system, the secondary steelwork may need to satisfy more onerous positional requirements, as described in the cladding manufacturers’ literature.

#### 4.4.2 Cleat position and orientation

Tolerances on the position and orientation of the purlin and side rail cleats (and therefore on the purlins and side rails themselves at the points where they intersect the primary steelwork) are included in the 5<sup>th</sup> edition of the NSSS<sup>[29]</sup>, under the general heading ‘tolerances on attachments’. The following limits are given (see Figure 4.2):

- Position of the attachment with respect to the member setting out point -  $\pm 5$  mm
- Orientation of the attachment -  $\pm 1^\circ$ .

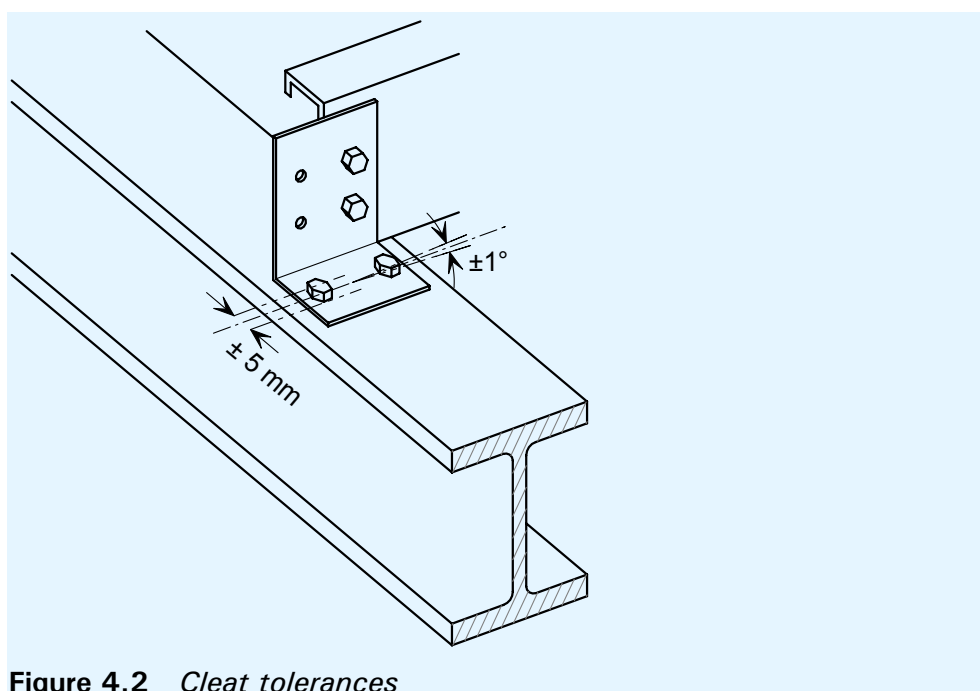


Figure 4.2 Cleat tolerances



It is worth noting that the positional tolerance of  $\pm 5$  mm relative to the setting out point could result in a tolerance of  $\pm 10$  mm on the spacing of the purlins or rails. This is important in terms of cladding panel lengths, especially for insulated panels. The rotational tolerance of  $\pm 1^\circ$  is equivalent to a slope of 1 in 60.

#### 4.4.3 Purlin/rail position at mid-span

Tolerances (as opposed to deflection limits) are not normally given for the position of a member within its length, since this depends not only on the initial out-of-straightness of the member (a rolling tolerance), but also on its deflection under the action of its self-weight plus the weight of the cladding. This latter point is an issue for the specifier and is, therefore, outside the scope of the erection tolerances given in the NSSS. However, excessive purlin and side rail sag is sometimes a problem for the cladding community, leading to difficulties on site and potentially compromising the airtightness, structural integrity and non-fragility of the building envelope. This suggests that there is a need for tolerances on the mid-span position of purlins and rails, together with guidance on how these recommendations might be achieved in practice.

As noted earlier, the maximum allowable purlin or side rail sag is governed by the ability to fix the cladding and achieve an airtight seal. The suggested limits given below in Table 4.1 are, therefore, dependent on the type of cladding and should be read in conjunction with any product-specific guidance issued by the cladding manufacturer. Where built-up cladding systems are used, the provision of a lap between the liner sheets allows moderate deviations to be accommodated. However, the lack of such a lap in insulated panels, together with strict end bearing requirements and manufacturing tolerances on the panel length, mean that greater care is needed to facilitate fixing of the panels to the purlins or side rails in this case.

The critical tolerance from a cladding contractor's point of view is the down-slope position of the top flange of the purlin at the time that the cladding is fixed. The recommended maximum deviation of the purlin is  $\pm x$ , as illustrated in Figure 4.3. This tolerance is applied to the position of the purlin relative to a fixed datum point in order to prevent the build-up of cumulative tolerances over the length of the roof slope. The same value  $x$  is also applied as a tolerance on the spacing between the purlins. Suggested values of  $x$  are given in Table 4.1 for insulated panels and built-up systems. These suggested limits may also be applied to the vertical position and spacing of side rails supporting wall cladding.

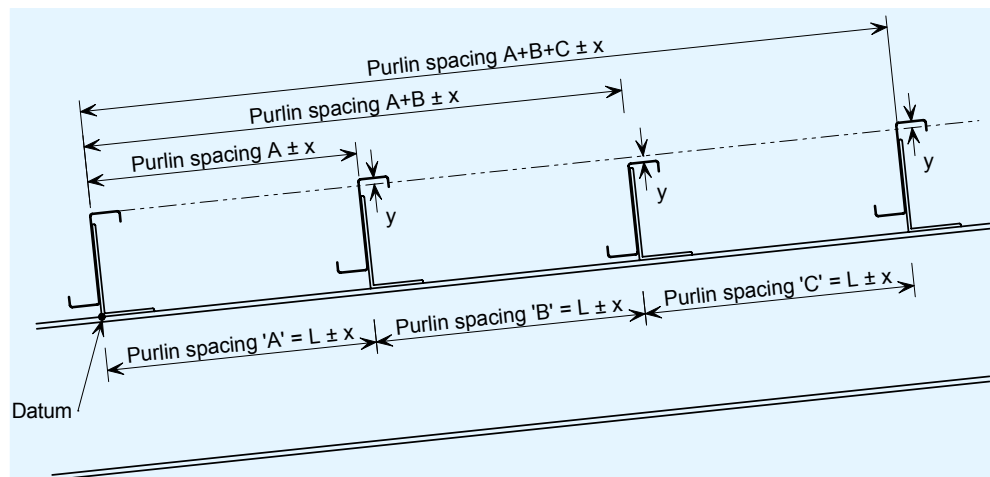


Figure 4.3 Limits on purlin position

**Table 4.1** Allowable deviations in purlin position

Type of cladding	Allowable sag $x$
Insulated panels	10 mm
Built-up systems	20 mm

The 10 mm value for insulated panels is based on a purlin flange width of 65 mm. Specifiers may select a purlin section with a wider flange or consider the addition of a light gauge steel angle or plate to provide a wider bearing surface for the roofing/cladding, thereby allowing a relaxation in the limits given in Table 4.1. However, as there are cost implications associated with both of these options, it is essential that they are discussed with the roofing/cladding sub-contractor and steelwork contractor before the award of either contract and that the preferred solution is agreed by all parties.

Rooflights require special consideration, as the fasteners connecting them to the purlins need to be positioned within a narrow zone around the perimeter of the rooflight. The width available for the fasteners, and hence the tolerance on the purlins, depends on the type of rooflight.

The dimension  $y$  in Figure 4.3 is the allowable variation in the top flange level of the purlin with respect to a datum line running parallel to the rafter. The maximum allowable value of  $y$  is dependent on the type of cladding and, in particular, on its ability to flex without sustaining damage. Limiting values of  $y$  may be obtained from the cladding manufacturers' technical literature.

#### 4.4.4 Purlin rotation within the span

Where built-up cladding systems are specified, the positional requirements for the purlin (see Section 4.4.3) should also be applied to the top of the spacer system in order that the outer cladding sheets may be installed correctly. The alignment of the top of the spacer system is governed by the position of the purlin and the rotation of the top flange of the purlin relative to the plane of the roof. As built-up cladding systems have become deeper, so the effect of the purlin flange rotation has become more significant. For example, if a purlin undergoes a twist of  $3^\circ$  relative to the rafter, the corresponding misalignment at the top of a 180 mm deep spacer system is 22 mm, as shown in Figure 4.4.

In the case of insulated panels, which generally possess a relatively high bending stiffness, excessive purlin twist could prevent the panels from seating properly on the top flange of the purlin. This is likely to cause difficulties for the cladding installation contractor and, if the rotation of the top flange is sufficiently severe, could prevent a proper connection from being made between the panel and the purlin.

Most standing seam roof systems are sensitive to purlin rotation and the manufacturer's recommended rotation tolerance can be as low as  $\pm 1^\circ$  in some cases.

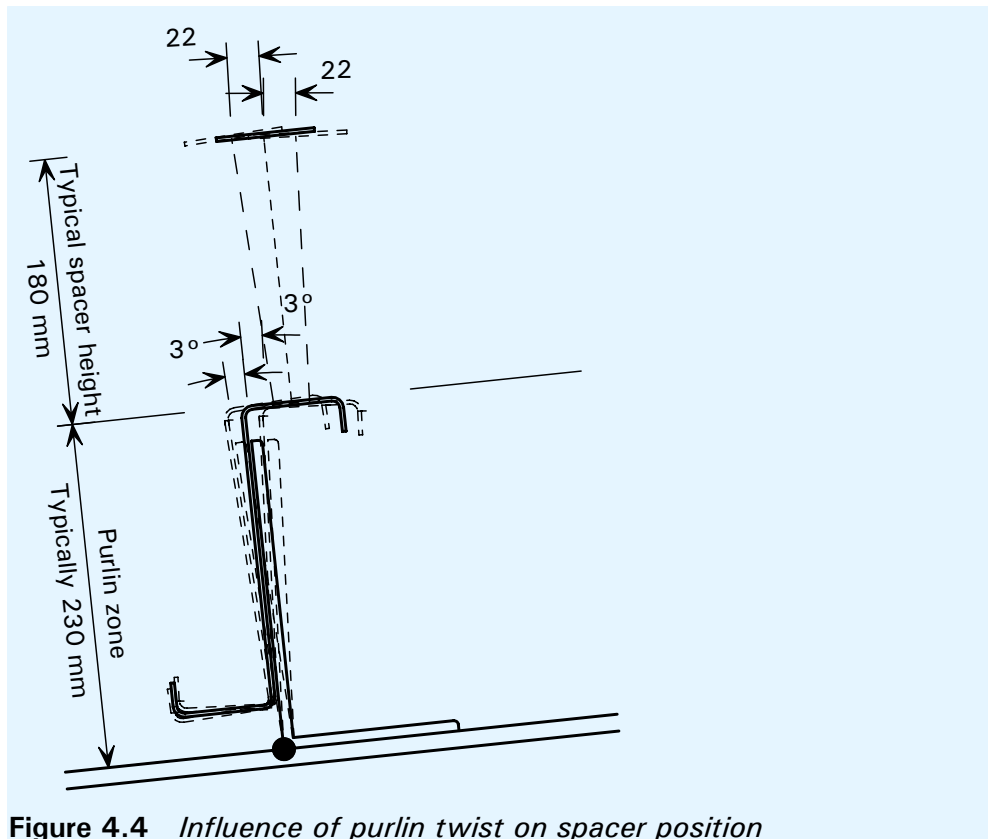


Figure 4.4 Influence of purlin twist on spacer position

#### 4.4.5 Achieving the required tolerances

There are several potential reasons for the problems that cladding contractors sometimes encounter regarding the condition of the purlins and side rails, covering a range of activities from specification to installation. These activities are listed below, together with guidance on the steps that should be taken in order to avoid poor alignment and excessive sagging of the secondary steelwork.

##### **Specification**

- Select a purlin Section that will not sag excessively under the action of its own self-weight plus the appropriate weight of cladding at the time of the cladding installation, taking into account the proposed span and the provision of anti-sag rods. For the purpose of this calculation, the weight of cladding should be taken as the weight of the insulated panels or that of the liner, depending on the chosen cladding type.
- Where appropriate, specify anti-sag rods to limit the down-slope sag of the purlin. The purlin manufacturers will normally indicate the spans above which anti-sag rods are needed, but they should also be considered at shorter spans where particularly tight tolerances are required.

##### **Manufacture**

- Ensure that the purlins and side rails are manufactured to the tolerances set out in BS 5950-7. There should be little difficulty meeting this requirement when the secondary steelwork is purchased from a reputable supplier in the United Kingdom.

### ***Transport, handling and storage***

- Take care to avoid damage during the transportation of the purlins and rails to site and when handling these components on site. Even small deformations caused by handling can cause difficulties during erection.
- Ensure that all steelwork is stored in a safe location (where it will not be damaged by traffic or site plant) and that it is correctly supported.

### ***Fabrication and erection***

- Install all attachments to the steel frame, including the cleats for the purlins and rails, in accordance with the tolerances given in the NSSS and Section 4.4.2 of this publication.
- When erecting the secondary steelwork, pay particular attention to the joints between members to ensure that the surface onto which the cladding is to be attached is straight, flush and free of lips, steps or other obstructions.

### ***Cladding installation***

- Do not subject purlins that are not fully restrained (by insulated panels or by a non-perforated steel liner) to any construction loads, other than over the rafters, unless they have been specifically designed to carry these loads in this condition. Unrestrained purlins are much less able to carry load than restrained purlins.
- Begin the installation of the cladding at the rafter and progress into the span of the purlin, fixing each sheet as it is laid. The sheets should be fully fixed with all fasteners installed.

## **4.5 Erection sequence and related issues**

This Section contains general guidance on the erection of purlins and side rails, based on the recommendations of some of the United Kingdom's leading suppliers. Most purlin and side rail manufacturers provide detailed recommendations on the use of their products, including recommended erection sequences and requirements for the provision of temporary supports and restraint. The guidance presented in this publication is not intended as a substitute for the manufacturer's advice, since each system is likely to have its own specific requirements. However, many of the recommendations are common to all systems and are worth repeating here.

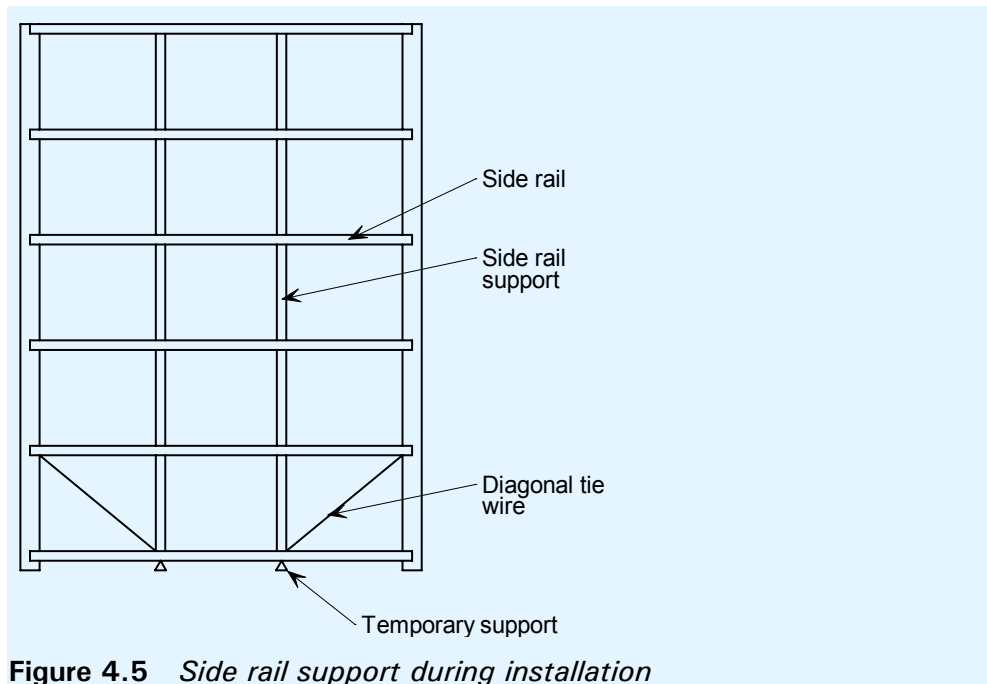
### **4.5.1 Side rails**

The simplest way of ensuring that the side rails are spaced correctly is to install perpendicular supporting members as shown in Figure 4.5. However, on their own, these supports are only capable of holding the rails in position relative to one another and will not prevent the entire rail system from sagging. To overcome this problem, the manufacturers recommend fixing the rails from the bottom up, with temporary supports placed beneath the bottom rail if required.

The recommended erection sequence is described below (see Figure 4.5):

1. Fix the bottom rail in position.
2. Where necessary, place temporary props beneath the bottom rail and adjust the height so that a level line is achieved
3. Fix the second rail.

4. Fix the vertical side rail supports and diagonal tie wires and adjust to ensure that both horizontal rails are level.
5. Remove the temporary props (unless the cladding is designed to be suspended from the eaves beam, in which case the props must be left in place until the completion of the side rail installation).
6. Fix the remaining rails and supports progressively up the building.



**Figure 4.5** *Side rail support during installation*

#### **4.5.2 Purlins**

The installation of the purlins should start at the eaves and progress up the slope to the apex. For short spans on low pitch roofs, it may be possible to install the purlins with no down-slope support between the rafters. Where this is attempted, the steelwork erectors should ensure that the sag at mid-span is within the recommended limits given in Section 4.4. Where intermediate support is necessary, this should be achieved by means of anti-sag bars placed either at mid-span or at 1/3 span intervals (see Figure 3.5).

The purlins should be installed one row at a time, followed immediately by the anti-sag bars (if required), before proceeding to the next row. This will prevent the accumulation of errors. The support at the bottom of the slope will be provided by the eaves beam, so there should be no need to provide temporary props in this case.

## 5 CLADDING INSTALLATION

### 5.1 Introduction

The functional performance of the building envelope is dependent on the correct specification of the individual components that make up the cladding system, the manufacturing quality of these components and the standard of installation. As discussed earlier, good performance also requires a high degree of interaction between the components within each system and between systems (e.g. between the frame and the cladding). This interaction requires the specification of components that complement one another and the ability and willingness of the specifier to take a ‘whole building’ approach to the design process. Good interaction also requires high standards of construction, especially where the connections between components are concerned.

The aim of this section is to provide practical guidance to site practitioners on the installation of roof and wall cladding to enable the building envelope to function as specified without the need for costly remedial works. There are two principal drivers behind this guidance:

- Part L of the Building Regulations.
- Health and Safety during the installation process.

### 5.2 Preparation

The first steps to ensuring safe, efficient and trouble-free cladding installation should be taken well before any cladding materials or cladding installation operatives arrive on site. These include planning the logistics of the materials supply to site, producing detailed method statements for the site-based operations and programming the work sequence for the cladding installation activities.

Well before the cladding contractor starts work on site, a detailed cladding sequence should be established. This sequence should be discussed with the main contractor and designer during pre-contract stages and in design meetings in order to ensure that it fits in with the other site activities programmed for the same period. The sequence must also recognise the assumptions made during the design process, such as the provision of restraint and the magnitude of construction loads. It is important for the cladding contractor to discuss requirements for off-loading, storage and lifting of materials with the main contractor in order to avoid clashes with other site operations.

Prior to the delivery of the cladding materials to site, the main contractor should ensure that the ground surrounding the building is properly prepared to receive the delivery vehicles and their loads. This includes the provision of a storage area and suitable road access to this area. The cladding materials are typically delivered on trailer units up to 16 m long and access will be required for the vehicle to manoeuvre around all sides of the building. Suitable standing and off-loading locations should be chosen in advance, taking into account the size and weight of the delivery vehicle and the requirements of the cladding contractor’s crane. Consideration must be given to the safe reach distance for the chosen crane and any obstructions to the lifting of materials from the ground to the roof level.

As noted in Section 4.4, the failure to erect the purlins and side rails correctly can lead to difficulties for the cladding contractor, which in turn could prevent the cladding from functioning properly (e.g. increased air leakage). **Some time prior to commencing installation, it is advisable for the cladding contractor to carry out a visual inspection of the secondary steelwork. Any obvious problems should be pointed out to the main contractor immediately to allow remedial work to be undertaken before the cladding contractor begins work.**

### 5.3 Handling and storage

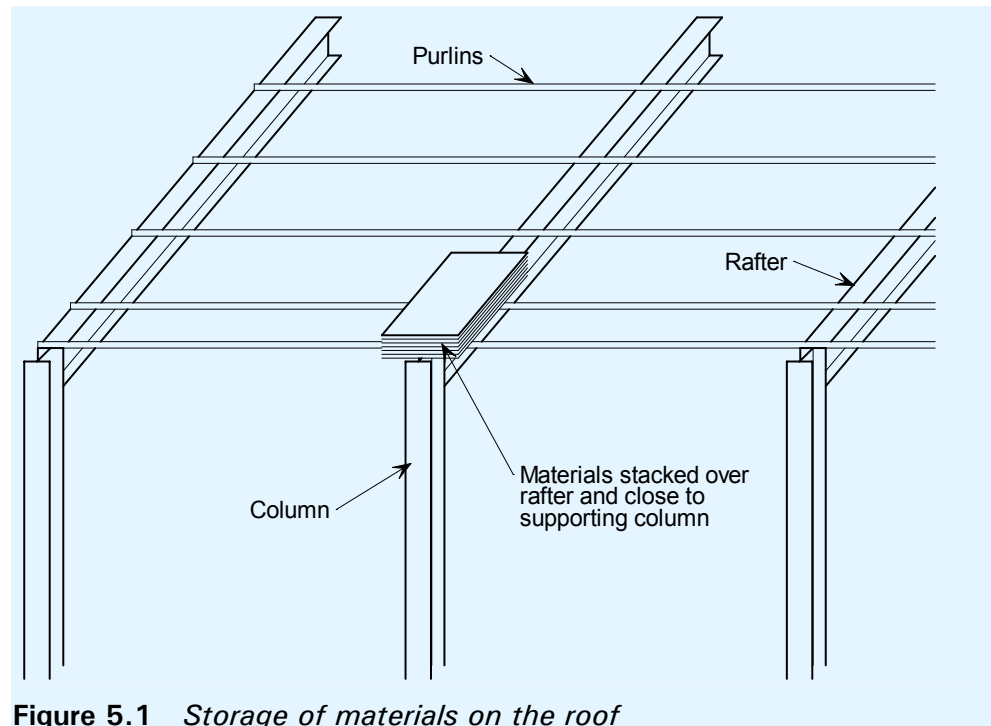
When the cladding materials first arrive on site, the consignment should be checked against the cladding programme and drawings to ensure that the correct components have been delivered. The materials should be clearly labelled or tagged with all the relevant information such as sheet thickness, profile dimensions and, in the case of insulated panels, the pack contents and weight, together with any relevant certification. A visual inspection should also be made for damage that might have occurred during transit.

Whether built-up systems or insulated panels are used, the cladding will normally be packed into bundles for ease of transportation. Typically, these bundles weigh between 1 and 2 tonnes and will be unloaded by means of a crane or forklift. This lifting operation must be carried out in accordance with the appropriate safety regulations and should be supervised by a competent person. **To reduce the risk of damage during the lift, only protected chain slings or synthetic slings should be used. Bare steel chain slings should not be used, as these tend to damage the edges of the thin metal sheets.** In order to ensure that the panels or sheets are properly supported during the lift, it is good practice to attach the slings to a lifting beam, rather than attaching them directly to the crane hook.

The cladding contractor should plan the cladding deliveries to ensure the timely supply of materials to the site. This will allow uninterrupted progress of the cladding operation, with only a minimum requirement for storage on site. Even with this approach, it is likely that some of the cladding will need to be stored on the ground prior to installation and it is important that a suitable location is found for this purpose. The storage location should be assigned in advance of the delivery and agreed between the cladding contractor and main contractor. It should be close to the final destination of the cladding on the building and easily accessible. However, it should also be clear of any access roads or other heavily trafficked areas where the panels or sheets might be at risk of damage from passing plant or vehicles. Whenever possible, the roof cladding packs should be off-loaded directly from the delivery vehicle onto the roof. This avoids costly double-handling and reduces the risk of damage.

Where the roof is used to store materials, the cladding contractor should ensure that the additional loading does not cause any damage to the supporting structure or compromise the safety of the workforce or other personnel. If necessary, the structural engineer responsible for the design of the primary and secondary steelwork should be consulted to ascertain its safe working load. Under no circumstances should this load be exceeded, even if only for a short length of time.

**Heavy packs of materials should always be placed over the rafters close to the supporting columns, as shown in Figure 5.1.** Loading materials onto the purlins at other locations (i.e. within the span of the purlin) could result in permanent deformation (sag) beyond the suggested limits given in Section 4.4, leading to difficulties in fixing the cladding and potentially compromising the airtightness and structural integrity of the building envelope. Care should be taken to avoid any damage to the purlins, cleats or rafters, bearing in mind that the concentrated loading from a pack of sheets or panels is likely to be more onerous than the distributed loading that the structure will experience once the cladding is fixed.



When selecting a storage location on the roof, careful consideration should be given to the final destination of the materials on the finished building in order to minimise the requirements for manual handling. Stacks containing non-identical items (e.g. different lengths of sheet), should be arranged in the correct order ready for use to avoid unnecessary sorting and handling on the roof. Although packs of sheets are often heavy, individual sheets are sufficiently light that they can be blown off the roof by strong wind gusts. It is, therefore, important that cladding sheets are always secured firmly against wind uplift.

## **5.4 Fixing built-up cladding and insulated panels**

### **5.4.1 Health and Safety**

All construction activities in the United Kingdom, including the installation, maintenance and removal of roof and wall cladding, are governed by Health and Safety legislation, including the following Acts and Regulations:

- Health and Safety at Work etc. Act 1974<sup>[32]</sup>
- Construction (Design and Management) Regulations 1994<sup>[2]\*</sup>
- Construction (Health, Safety and Welfare) Regulations 1996<sup>[33]\*</sup>



\* These regulations are due to be replaced in April 2007 by revised Construction (Design and Management) Regulations.

While the specific regulatory requirements vary according to the nature of the work being undertaken, the general underlying principle is that all hazards should be identified and, where possible, eliminated. Where elimination of a hazard is not possible, safe systems of work should be developed in order to minimise the risk to the operatives involved in the work, other personnel working on or near the construction site and members of the public. These safe systems of work should be clearly defined and presented in the cladding contractor's method statement.

Although there are similarities between projects, every site will have its own specific hazards and associated risks. It is therefore essential that a risk assessment is performed before every project and that any site-specific issues are properly addressed in the method statement. **Work should not be permitted to start until the risk assessment has been conducted, the method statement has been written and the required safety equipment and trained personnel are in place.** The details of the method statement will naturally vary from one project to another, but the following topics should be common to all:

- Agreement on cladding sequence
- Provision of access and egress
- Provision of a safe working platform
- Use of safety nets and other fall-arrest equipment
- Method of fixing panels and sheets
- Materials handling
- Use of cranes, cherry pickers and other plant
- Fragility of roof materials
- Supervision of workforce.

Guidance on writing effective method statements for work on profiled sheeted roofs is given in Annex A of ACR[CP]001:2003 *Recommended practice for work on profiled sheeted roofs*<sup>[34]</sup>.

It is important for clients and main contractors to recognise the role played by sub-contractors in creating a safe workplace and, with this in mind, to appoint sub-contractors who are competent and experienced in the type of work to be undertaken. The appointed cladding sub-contractor should ensure that only competent operatives with the relevant skills and qualifications are employed. It is especially important that the site supervisor is competent in his supervisory duties and possesses the necessary practical experience and knowledge to be able to implement the method statement fully. Inexperienced operatives should be given formal Health and Safety training before starting work and should be supervised at all times.

Some of the greatest risks during the cladding installation activities are associated with operatives working at height and materials falling from height. Particular attention needs to be paid to both of these issues in terms of providing a safe working platform from which the cladding operations can take place, a suitable means of access and egress, and effective barriers to prevent falls of

either people or materials. Wall cladding installation is generally carried out from cherry pickers or scissor lifts as shown in Figure 5.2, which provide safe access and a safe working platform. Roof cladding installation, however, involves operatives walking on the partially-constructed roof and, therefore, exposes the workforce to additional hazards, such as fragile roof cladding and unprotected gaps or edges. Guidance relating specifically to the installation of roof cladding is given in Section 5.5.



**Figure 5.2** *Wall cladding installation* (Image courtesy of C A Roofing)

#### **5.4.2 Installation issues**

Tests on real buildings and laboratory tests on individual components have demonstrated a clear relationship between the standard of cladding installation and air leakage. Indeed, the quality of construction is as important as the specification, since poor workmanship, such as incomplete runs of sealant or missing fasteners, can ruin the thermal performance of even the highest specification system.

The following issues require particular attention:

- Installation sequence
- Fasteners
- Joints and seals
- Details at interfaces.

Obtaining agreement between the cladding contractor and main contractor on the cladding installation sequence is clearly important in terms of site management and the avoidance of clashes between trades on site. Less apparent is the need to involve the structural engineer in discussions regarding the cladding sequence. However, several key design assumptions rely on the interaction between the structure and envelope, including the provision of restraint to the primary and secondary steelwork under construction loads. For this reason, the

cladding sequence should be shown on the appropriate contract drawings and any changes should be discussed with the structural engineer, so that the structural implications may be assessed. The cladding installation sequence may also be important in terms of forming the laps between the sheets and obtaining airtight joints at interfaces. Where the cladding manufacturers provide specific recommendations for the installation of their products, these should be followed carefully.

It is good practice to temporarily fix the insulated panels or sheets as they are laid, in order that they may be properly aligned. Where insulated panels are used, the installers should check that the bearing length on the purlins or rails is sufficient and that it is possible to install all of the required fasteners into the supporting steelwork. Bearing is less of an issue for built-up systems, due to the long end lap between sheets, but accurate alignment is important to allow the sheets to be fastened correctly and to obtain good quality airtight joints.

**Once the panels or sheets have been correctly aligned, it is important that they are fully fixed as soon as possible in order to provide lateral restraint to the supporting steelwork and to provide the required resistance to wind suction (uplift on roofs).** It is especially important that the cladding is fully fixed at the end of the working day to prevent damage from strong winds overnight. In this context, the term “fully fixed” means that the panels or sheets are fixed to every purlin or rail at the correct pitch according to the specification and the manufacturer’s recommendations. Supervisors should check that this is done, as insufficient fixity could result in the catastrophic failure of the building envelope during periods of high wind loading. Note: Liner sheets are not generally designed to take wind loads and should not, therefore, be left exposed for prolonged periods.

The joints between adjacent panels or sheets should be sealed in accordance with the cladding manufacturer’s recommendations. Most sealants are sensitive to the conditions of use, in particular the ambient air temperature (which affects the viscosity and flexibility of the sealant) and the condition of the surface to which the sealant is to be applied. Installers should, therefore, take care to follow the sealant manufacturer’s instructions regarding the use of their product and ensure that it is not used outside any recommended temperature limits or for applications for which it is not well suited. There is clearly a related responsibility on the specifier to select a suitable sealant for the particular application and likely site conditions.

Interfaces between sections of cladding (e.g. between masonry dwarf walls and metal cladding) are often a source of air leakage and require careful attention to detail on site. It is especially important that all flashings, fillers and other components are installed according to the specified details and that all joints are properly sealed.

## **5.5 Special considerations for roofs**

### **5.5.1 Working at height**

As noted in Section 5.4.1, many of the hazards associated with cladding installation stem from the need for operatives to work at a significant height above the ground. This is especially true for roof cladding operations due to the practice of using the partially constructed roof as a working platform. The

two principal categories of hazard for operatives or their supervisors working on a roof are:

- Falls through fragile roofs or gaps in the roof
- Falls from the edge of the roof.

**Current Health & Safety guidance, as given in HSE publication HS (G) 33 *Health and safety in roof work*<sup>[35]</sup> and ACR[CP]001:2003 *Recommended practice for work on profiled sheeted roofs*<sup>[34]</sup>, is that safety nets should be used as the preferred means of preventing falls through fragile roofs or gaps in the roof, as shown in Figure 5.3.** The nets should be fitted as close as possible to the underside of the roof and should cover the bay ahead and the bay behind the current work location (i.e. a minimum of 3 bays). Personnel should not enter the area above the final netted bay unless it is the last bay of the building. Safety nets should always be installed and regularly inspected by a competent person who has been trained and assessed to FASET (Fall Arrest Safety Equipment Training) standards. They should only be removed when the appropriate section of roof has achieved a ‘non-fragile’ status (see Section 5.5.2). Further guidance on the removal of nets is given in Annex B of ACR[CP]001:2003 *Recommended practice for work on profiled sheeted roofs*.



**Figure 5.3** *Safety nets and guardrail in place during roof cladding installation* (Image courtesy of C A Roofing)

Harnesses may also be used as a means of fall arrest provided that they are attached to suitable anchorage points and that those using them have received the necessary training. However, unlike safety nets, harnesses do not allow free movement over the roof. Operatives might, therefore, be tempted to detach their harnesses to access locations that would otherwise be out of reach. Where harnesses are used, it is important that the adequacy of the supporting structure is checked for the harness loads in combination with any other construction loads that are present at the same time. Where harnesses are required to be worn over part of a roof area, this area should be clearly denoted by signs and protected by physical barriers.

Falls from the edge of the roof should be prevented by the installation of a suitable guardrail, which must remain in place for the duration of the roof works (see Figure 5.3). In some instances, it may be preferable to construct an independent scaffold rather than attaching the barrier to the building frame, since the former option also provides a means of access along the building and may be used as a platform for unloading materials. Access and egress to and from the roof should be provided by scaffold access towers. These should be designed and installed by a qualified specialist.

Detailed guidance on the safe installation and maintenance of roofs is given in HSE publication HS (G) 33 *Health and safety in roof work*<sup>[35]</sup> and ACR[CP]001:2003 *Recommended practice for work on profiled sheeted roofs*<sup>[34]</sup>.

### 5.5.2 Fragility of roof cladding

The term fragility in the context of roof cladding refers to the ability of the cladding to support the weight of operatives and materials and any dynamic loading arising from walking, falling or the dropping of objects. Although falls through fragile cladding are often associated with maintenance activities on existing roofs clad with other forms of roofing (e.g. fibre cement sheets), modern profiled metal systems are not immune from such accidents, especially during construction. **It is essential that the fragility status of the roof is known at all times during the construction process and that the necessary precautions are taken to protect operatives working on the roof.**

The ‘non-fragile’ status of cladding products or assemblies should not be assumed without supporting evidence, usually in the form of test results obtained by the cladding manufacturer. ACR[M]001:2005 *Test for non-fragility of profiled sheeted roofing assemblies (third edition)*<sup>[3]</sup> presents detailed recommendations for the execution of fragility tests together with a system of classification for roof constructions. ACR[CP]001:2003 *recommended practice for work on profiled sheeted roofs* contains advice on when the nets can be removed.

Fragility is not simply a matter of material strength and profile shape, but also depends on such parameters as the span of the cladding, the design of the supporting structure and the number, quality and position of the fixings. Guidance on this matter is given in ACR[CP]001:2003 *Recommended practice for work on profiled sheeted roofs*. It is especially important that the cladding contractor ensures that the liner sheets are fully fixed before the nets are removed, since the omission of fasteners could invalidate the non-fragile status of the roof.

**Nominally ‘non-fragile’ assemblies may also be rendered ‘fragile’ by constant foot traffic or by heavy loads caused by stacked materials, operatives or plant. For this reason, the liner sheets, even when fully fixed, should not be used as a means of access or as a working platform, unless the profile has specifically been chosen for this purpose (i.e. 32 mm deep, 0.7 mm thick trapezoidal steel profile).**

Special care needs to be taken when working around rooflights as these are often made from fragile materials. Rooflights should never be walked on.

### 5.5.3 Fixing roof cladding

#### *Insulated panels*

The first line of cladding panels (known as a tier) should be laid out close to the rafter and temporarily fixed, starting from the eaves and progressing parallel to the rafter as far as the ridge. During this operation, care should be taken to avoid walking on the purlins, as this is likely to cause damage. The cladding installation should then proceed away from the rafter into the span of the purlins one tier at a time, as shown in Figure 5.4. Each tier of panels should be fixed to the purlins before the next tier is laid, in order to provide restraint to the purlins and reduce the risk of damage under construction loads.

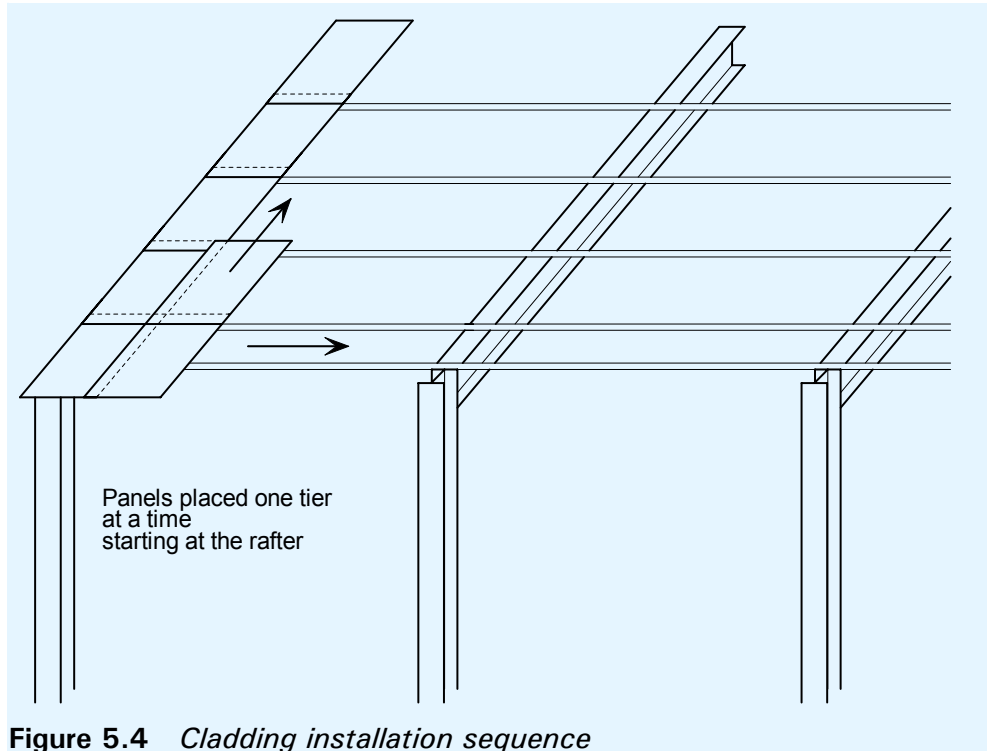


Figure 5.4 Cladding installation sequence

#### *Built-up systems*

The installation procedure for built-up cladding differs fundamentally from that for insulated panels in that the liner, spacer system, insulation and weather sheets are installed as individual components. This raises some important Health & Safety issues, particularly relating to the fragility status of the roof in the temporary condition.

It is common practice to lay out the liner sheets over part of the roof (e.g. 2 bays) and to temporarily fix them in position while they are checked for alignment and cover width. This operation should commence at the rafters and proceed into the span of the purlins, with the cladding installers working off 'Youngman' boards or similar stagings, as shown in Figure 5.5. Once the liners have been correctly aligned, they should then be fully fixed, before proceeding to install the spacers, insulation and finally the weather sheets.

Cladding supervisors should note that, until the liner sheets have been fully fixed in accordance with the manufacturer's recommendations, they should not be assumed to offer any restraint to the purlins or provide a non-fragile barrier against falls. Furthermore, even when fully fixed, it is generally considered to be bad practice to walk or stand on thin gauge low profile liner sheets due to

the risk of damage to the sheets. In addition to the loss of non-fragility discussed in Section 5.5.2, permanent deformation caused by excessive loading could lead to widening of the joints between sheets and, therefore, the loss of an airtight seal. Some roofing contractors seek to avoid such problems by using weather sheet profiles to form the liner (i.e. trapezoidal steel profiles 0.7 mm thick and at least 30 mm deep). This solution is naturally more expensive in terms of material costs, but offers benefits in terms of safety and speed of installation.



**Figure 5.5** *Liner sheet installation progressing into the span of the purlins with the installer working from a 'Youngman' board*  
(Image courtesy of C A Roofing)

## 6 CONCLUSIONS

Within Sections 2 to 5, certain statements are highlighted as ‘key points’. These key points are repeated below, with reference to the Section in which they occur in parentheses.

### 6.1 Cladding specification

#### *Weathertightness (2.2)*

Not all types of roof cladding are suitable for use on low pitch roofs. Specifiers must pay careful attention to the minimum pitch recommended by the manufacturers, together with the published guidance on detailing and installation.

Side and end laps in profiled sheeting are weak points in the building envelope, where the wind and rain could potentially penetrate the cladding. The design and construction of the laps is critical to the weathertightness of the cladding system.

#### *Appearance (2.3)*

In choosing the finish, the architect should bear in mind the influence of the profile shape on the overall appearance by making an allowance for the effects of reflection and shadow on the perceived shade of colour.

#### *Thermal performance (2.4)*

Compliance with the Regulations must be demonstrated using a whole building calculation model, such as the Simplified Building Energy Model (SBEM).

The adoption of whole building modelling, together with the diminishing returns obtained from further reductions in *U values*, mean that more emphasis in future is likely to be placed on airtightness and the performance of mechanical services, rather than ever increasing insulation thicknesses.

#### *Durability (2.7)*

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.

#### *Purlin and side rail restraint (2.9)*

The cladding specifier must ensure that the chosen cladding system is capable of providing the required degree of restraint and that it is appropriately detailed.

### 6.2 Purlin specification

#### *Purlin loading (3.2)*

The cladding installation sequence can have a significant effect on the buckling resistance of a purlin and, therefore, its load carrying capacity. This must be accounted for when specifying the purlins.



### ***Purlin deflections (3.3)***

Excessive deflection under self-weight, or under the action of construction loads prior to the fixing of the cladding, can lead to difficulties for the cladding installation.

### ***Restraint (3.6)***

It is essential that a level of restraint equal or greater than that assumed by the purlin manufacturers in their safe load tables is achieved in practice.

Tests and analysis to Eurocode 3 have shown that sufficient lateral restraint for the gravity load case is provided by conventional insulated panels (provided the number and strength of fixings is adequate) and non-perforated steel liners down to 0.4 mm thickness.

Purlin manufacturers give guidance on which types of cladding they consider to be adequate to restrain their purlin systems in the uplift condition. This guidance should be followed carefully.

## **6.3 Purlin installation**

### ***Handling and storage (4.2)***

To reduce the risk of damage during lifting operations, only protected chain slings or synthetic slings should be used. These should be positioned so as to provide adequate support and prevent excessive sag during the lift.

All light gauge steelwork should be placed on wooden or concrete blocks to keep it clear of the ground and to allow slings to be removed without being damaged and attached again for future lifting.

### ***Installation (4.3)***

The installation of the purlins and side rails should be performed from mobile access platforms (cherry pickers or scissor lifts).

### ***Erection tolerances (4.4)***

Improper or inaccurate erection of the purlins or side rails not only creates difficulties for the cladding contractors, but can also invalidate the assumptions underlying the cladding specification. In extreme cases, poor erection could compromise the integrity of the building envelope, leading to failure of the building air permeability test.

The over-riding issue regarding erection tolerances for secondary steelwork is the ability of the cladding contractor to fix the cladding to the purlins and side rails, without compromising the airtightness, weathertightness or structural integrity of the building envelope.

Specifiers may select a purlin Section with a wider flange or consider the addition of a light gauge steel angle or plate to provide a wider bearing surface for the roofing/cladding, thereby allowing a relaxation in the limits given in Table 4.1. However, as there are cost implications associated with both of these options, it is essential that they are discussed with the roofing/cladding sub-contractor and steelwork contractor before the award of either contract and that the preferred solution is agreed by all parties.

## **6.4 Cladding installation**

### ***Preparation (5.2)***

Some time prior to commencing installation, it is advisable for the cladding contractor to carry out a visual inspection of the secondary steelwork. Any obvious problems should be pointed out to the main contractor immediately to allow remedial work to be undertaken before the cladding contractor begins work.

### ***Handling and storage (5.3)***

To reduce the risk of damage during lifting operations, only protected chain slings or synthetic slings should be used. Bare steel chain slings should be avoided, as these tend to damage the edges of the thin metal sheets.

Heavy packs of materials should always be placed over the rafter backs close to the supporting columns.

### ***Health and Safety (5.4.1)***

Work should not be permitted to start until the risk assessment has been conducted, the method statement has been written and the required safety equipment and trained personnel are in place.

Safety nets should be used as the preferred means of preventing falls through fragile roofs or gaps in the roof.

It is essential that the fragility status of the roof is known at all times during the construction process and that the necessary precautions are taken to protect operatives working on the roof.

Nominally 'non-fragile' assemblies may be rendered 'fragile' by constant foot traffic or heavy loads caused by stacked materials, operatives or plant. For this reason, the liner sheets, even when fully fixed, should not be used as a means of access or as a working platform, unless the profile has specifically been chosen for this purpose (i.e. 32 mm deep, 0.7 mm thick trapezoidal steel profile).

### ***Installation procedure (5.4.2)***

Once the panels or sheets have been correctly aligned, it is important that they are fully fixed as soon as possible in order to provide lateral restraint to the supporting steelwork and to provide the required resistance to wind suction.

## 7 REFERENCES

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\*These regulations are due to be replaced in April 2007 by revised Construction (Design and Management) Regulations