

CPD APPROVED

GD 24 INSTALLATION OF PURLINS AND SIDE RAILS

1.0 INTRODUCTION

The ability of a steel framed building to perform adequately depends on good interaction between the secondary steelwork and the cladding and crucial to this interaction is the correct installation of the purlins and side rails. The Metal Cladding and Roofing Manufacturers Association has updated chapter four of the Steel Construction Institute publication P346, *Best Practice for the Specification and Installation of Metal Cladding and Secondary Steelwork*. The resulting guidance document sets out an overview of the issues that need to be addressed in order to meet the performance criteria identified by the building designer.

The document offers good practice guidance on the storage, handling and installation of the secondary steelwork and associated components. 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.

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 organisations 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 document.

2.0 HANDLING AND STORAGE

2.1 Delivery

The purlins and side rails are normally delivered to site on articulated lorries approximately 16 metres long with a typical turning circle of 19 metres. 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.

2.2 Inspection

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.

2.3 Off-loading

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.

NOTE:

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.

3.0 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.

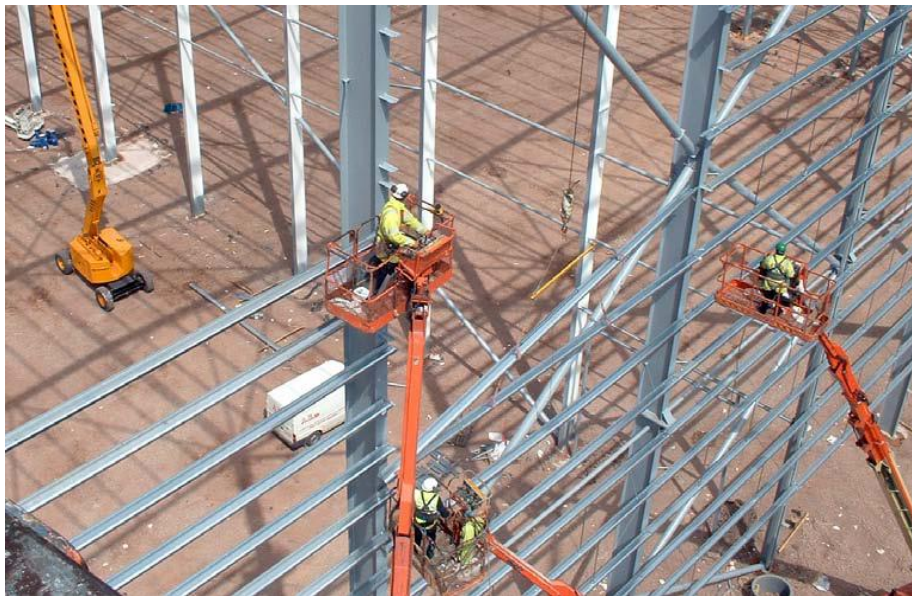


Figure 1 Side rail installation (Image courtesy of Barrett Steel Buildings Limited)

The installation of the purlins and side rails should be performed from mobile access platforms (cherry pickers or scissor lifts) as shown in Figure 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 (cf. ACR [M] 001:2014 Rev 5 (Red Book) *Test For Non-Fragility of Large Element Roofing Assemblies*).

4.0 ERECTION TOLERANCES FOR PURLINS AND SIDE RAILS

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 BS EN 1993-1-3:2006.

In addition, the 5th Edition of the *National Structural Steelwork Specification for Building Construction* (NSSS) incorporates 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, weather tightness 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 non-fragility classification of the assembled system, 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 NSSS 5th Edition and Section 4.2 of this document. 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 4.3 of this document. 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.

4.2 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 NSSS 5th Edition under the general heading 'tolerances on attachments'. The following limits are given (see Figure 2):

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

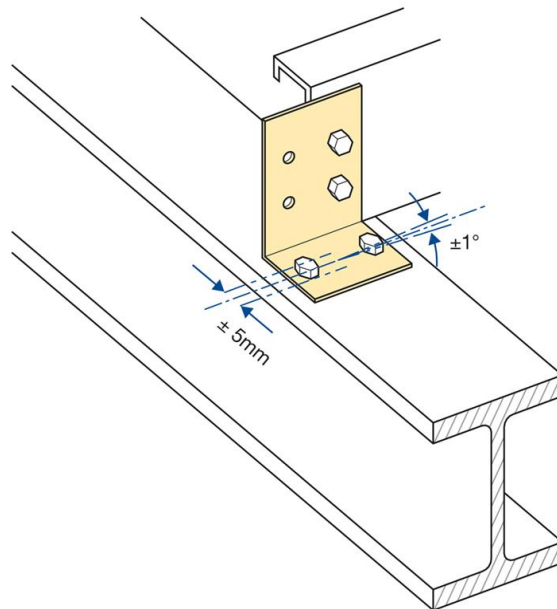


Figure 2 Cleat tolerances

It is worth noting that the positional tolerance of ± 5 mm relative to the setting out point could result in a tolerance of ± 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.

4.3 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 5th Edition.

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 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 downslope 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 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 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.

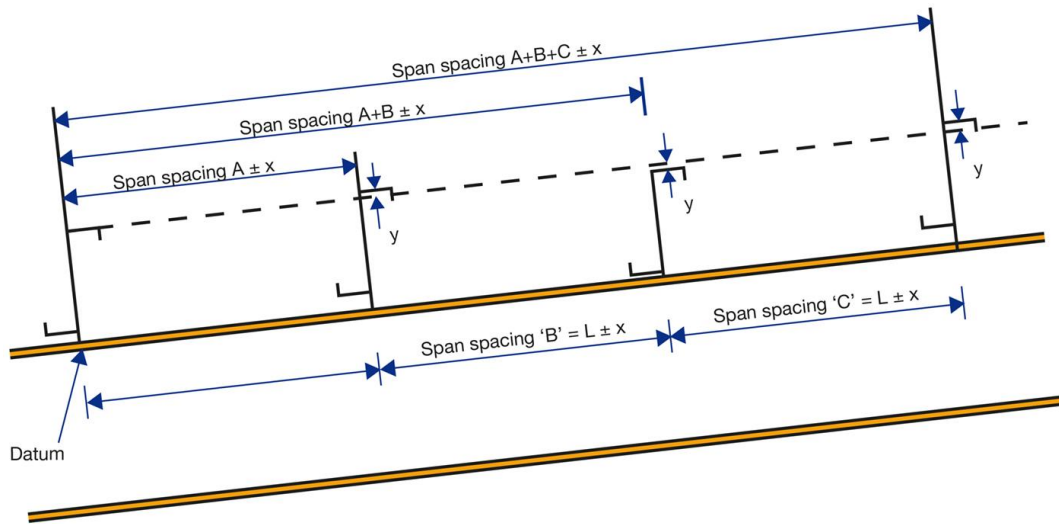


Figure 3 Limits on span position

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

Table 1 Allowable deviations in purlin position

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 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 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 PURLIN ROTATION WITHIN THE SPAN

Where built-up cladding systems are specified, the positional requirements for the purlin (see Section 4.2) 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° 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.

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.

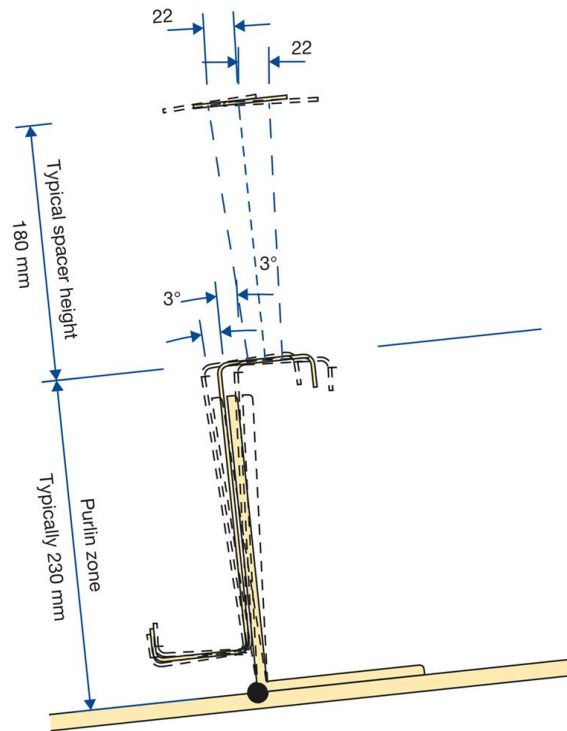


Figure 4 Influence of purlin twist on spacer position

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.

4.5.1 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 downslope 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.

4.5.2 Manufacture

Ensure that the purlins and side rails are manufactured to the tolerances set out in BS EN 1993-1-3:2006. There should be little difficulty meeting this requirement when the secondary steelwork is purchased from a reputable supplier in the United Kingdom.

4.5.3 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.

4.5.4 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 4.2 of this document.

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.

4.5.5 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.

4.6 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 document 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.

4.6.1 side rails

The simplest way of ensuring that the side rails are spaced correctly is to install perpendicular supporting members as shown in Figure 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 overleaf (see Figure 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.

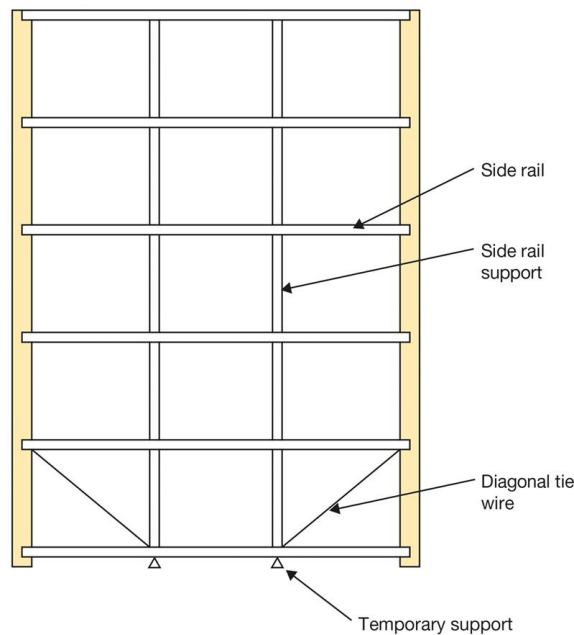


Figure 5 Side rail support during installation

4.6.2 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 4.3.

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 6).

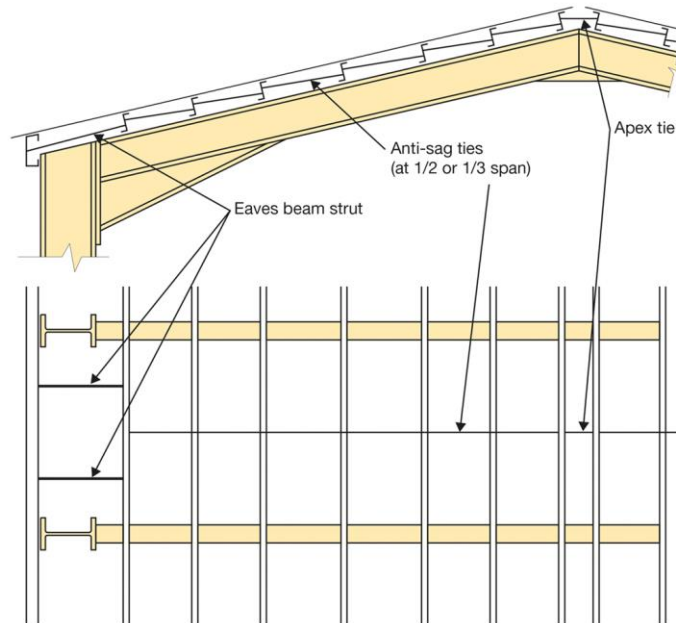


Figure 6 Typical anti-sag ties and eaves beam strut layout

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.

5.0 CONCLUSIONS

It is important that the installation criteria are set at the design stage and implemented at the construction stage to ensure that all elements of the construction perform as expected and also that the interface, interaction and fit between components and systems meet with expectations. If in doubt, seek the advice of a qualified structural engineer.

Without these criteria, the building will not perform correctly and the installation and attachment of component parts by follow-on trades will be compromised. Follow-on trades which are contractually responsible for accepting the condition of the earlier works prior to commencing the installation of subsequent components must ensure that the serviceability states and deflection criteria meet the design parameters for their products before proceeding.

Adoption by industry of the guidelines outlined in this document will lead to better and more consistent standards of metal roofing and cladding construction.

MCRMA member companies can advise on the suitability and performance of materials, systems and assemblies to ensure that the deflection criteria are calculated properly and that the cladding and components are specified accordingly. In addition, design information can be obtained from any of the independent roofing and cladding inspectors featured on the MCRMA web site at www.mcrma.co.uk

MCRMA ONLINE CPD PROGRAMME



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To take the CPD associated with this document go to www.mcrma.co.uk/online-cpds/

REFERENCES

ACR [M] 001:2014 Rev 5 (Red Book), *Test For Non-Fragility of Large Element Roofing Assemblies*

BS EN 1993-1-3:2006, *Design of steel structures. General rules. Supplementary rules for cold-formed members and sheeting*

Health and Safety Executive, *Manual Handling Operations Regulations 1992 (as amended)*,

Steel Construction Institute, *National Structural Steelwork Specification for Building Construction - 5th Edition CE Marking Version*

Steel Construction Institute P346, *Best Practice for the Specification and Installation of Metal Cladding and Secondary Steelwork*

USEFUL PUBLICATIONS

MCRMA guidance document GD13 *Non fragility of roofs - a checklist*

MCRMA guidance document GD20 *Guidance document on serviceability states and deflection criteria*

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