

CPD APPROVED

GD 20 SERVICEABILITY STATES AND DEFLECTION CRITERIA GUIDANCE

1.0 INTRODUCTION

The Metal Cladding and Roofing Manufacturers Association had noticed a gap in the published standards relating to the serviceability states for design. This has now been addressed in this document which also gives guidance on secondary steelwork installation tolerances.

In structural engineering, serviceability refers to the conditions under which a building is still considered useful. Should these limit states be exceeded, a construction that may still be structurally sound would nevertheless be considered unfit. It also includes conditions other than the building strength that might render a building unusable; such as durability, overall stability, fire resistance, deflection, cracking and excessive vibration.

MCRMA recommends that appropriate and workable serviceability states and deflection criteria affecting a roof and/or wall should be agreed at the outset and applied to the primary structure, secondary structure and the building envelope.

It is important that these 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. Without these criteria the building will not perform correctly and the installation and attachment of component parts by follow-on trades might be compromised.

Follow-on trades which are contractually responsible for accepting the condition of the earlier works prior to the installation of subsequent components must ensure that the serviceability states and deflection criteria meet the design parameters for their products before proceeding.

2.0 SCOPE

In the design of light gauge steel sheeting and purlins, British Standards define load factors and load combinations for ultimate limit state (ULS) design but do not give guidance on serviceability limit states (SLS).

Ultimate limit state (ULS) is basically the resistance to collapse.

Serviceability state (SLS) is about stiffness and limiting deflections.

This paper summarises current practice and guidance available, making reasonable recommendations for design. It is concerned with light gauge roof and wall sheeting and light gauge structural decking, steel purlins and sheeting rails.

It also includes a summary of secondary steelwork installation tolerances from the Steel Construction Institute (SCI) document P346 *Best Practice for the Specification and Installation of Metal Cladding and Secondary Steelwork*

3.0 DEFLECTION LIMITS

3.1 Why serviceability limits?

Serviceability limits concern the functioning of the structure under normal use, the comfort of building users and the appearance of the structure. Serviceability limit states (SLS) may be irreversible or reversible; with metal roofing and cladding the SLS are normally reversible (when none of the consequences remain after the actions have been removed) and the profile stresses are within the elastic region.

Criteria that might be considered during serviceability limit state design checks are:

- Deflections that affect the appearance of the structure, the comfort of its users and its functionality (cracking of fittings, movement of fittings, air tightness, water tightness, drainage, etc.)

- Vibrations that may cause discomfort to users of the structure and restrict the functionality of the structure (noise etc.)
- Damage that may affect the appearance or durability of the structure (distress to fixings and sealants, ceilings, fittings, ponding etc.)

The deflections of a profiled sheet under serviceability loads should not impair the strength or efficiency of the sheeting or of its fixings, or cause damage to flashings, insulation or waterproofing.

The dead load (permanent) should reflect the actual load acting on the part of the structure in question and the imposed load (snow and foot traffic) should reflect any temporary or transient load at the location. Wind loading should normally be assumed to be uniform on all spans of multi-span sheeting. The methods for calculating snow and wind loads acting on the roofing and cladding can be found on the MCRMA web site.

3.2 Historic advice

BS 5950 part 6 table 2 contained deflection criteria for decks. BS 5427:96 and MCRMA technical paper No 3 *Secret Fix Roofing Design Guide* contain the same table for roofing and cladding. The deflection criteria are repeated within the current draft revision of BS 5427- see table 1 below.

Normal maximum permissible deflection for profiled sheeting under distributed loads (L is the purlin spacing. L/500 is a more stringent limit than L/200)		
Load condition	Permissible deflection as a multiple of span	
	Roof cladding	Wall cladding
Dead	L/500	
Dead and imposed	L/200	
Dead and wind	L/90	
Wind		L/120

Table 1: Deflection criteria for decks

3.3 Current advice

BS EN 1993-1-3:2006 and BS EN 1990-2002 do not give deflection criteria.

BS EN 1991-1-3: 2006 7.2.1 and 7.2.2 states: "With reference to EN 1990 - Annex A 1.4 limits for vertical deflections according to Figure A 1.1 should be specified for each project and agreed with the client."

There is a variety of guidance available from manufacturers' literature and the standards authorities both in the UK and abroad for deflection under dead and imposed loads (permanent and variable loads). Typically:

Purlins: L/180 (under roof sheeting)
 L/360 (plasterboard ceiling),
 L/240 (non-plasterboard ceiling suspended from purlins),
 L/200 (no ceiling)
 L/150 (agricultural)

Profiled metal roof: L/150, L/200, L/90 (wind suction)

Profiled metal wall: L/150

3.4 MCRMA recommendations

Working with both historical guidance and manufacturers' guidance, the MCRMA recommendations are shown in table 2 below

Structural element (fittings = ceilings/services etc)	Purlins and structural deck (fittings = plasterboard/fragile types)	Purlins and structural deck (fittings = non-fragile types)	Purlins and structural deck (fittings = n/a)	Profiled metal roof sheeting (fittings = n/a)	Sheeting rails (fittings = n/a)	Profiled metal wall cladding (fittings = n/a)
Deflection limit-Dead (permanent) loads	L/500	L/500	L/500	L/500	n/a	n/a
Deflection limit-Dead + Live (permanent and variable) loads	L/360	L/250	L/200	L/200	n/a	n/a
Deflection limit-Dead + Wind/Snow drift loads (permanent and variable, as applicable)	L/150	L/150	L/150	L/90	L/90	L/90

*Table 2: Deflection limits: MCRMA recommendations
Note: Manufacturer's published guidance takes preference if different*

4 INSTALLATION TOLERANCES

4.1 Light gauge steel sheeting and cladding rails

There is little substantial tolerance guidance available for the installed positions of secondary steelwork - light gauge steel purlins and sheeting rails.

The absence of standards leaves setting and accepting them open to commercial and programme pressures, resulting in lower quality and impaired performance and durability.

The industry needs firm guidance that sets a reasonable benchmark for all to work with.

This is a long-standing problem and in 2005/6 the SCI chaired a working group from the industry which resulted in SCI document P346 *Best Practice for the Specification and Installation of Metal Cladding and Secondary Steelwork*.

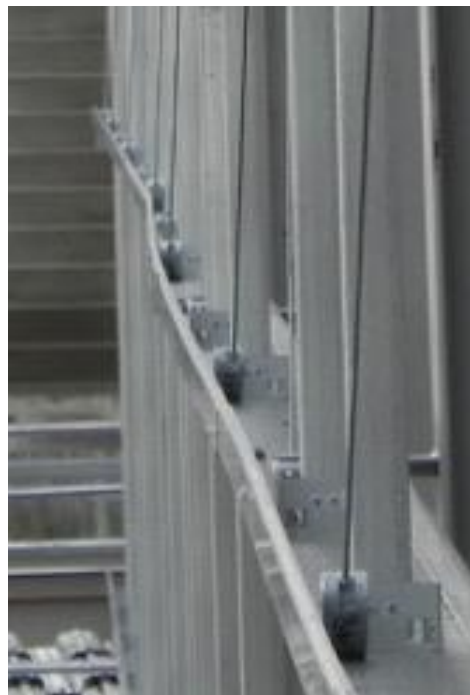
This document includes guidance on installation tolerances for purlins and rails supporting profile metal roof sheeting and wall cladding. The intention is to examine structure positioning from the point of view of the practicalities of installing a roof or wall covering. This is to give the installer the best chance of locating the purlin or rail and installing fasteners consistently.



Excessive purlin rotation before any load applied

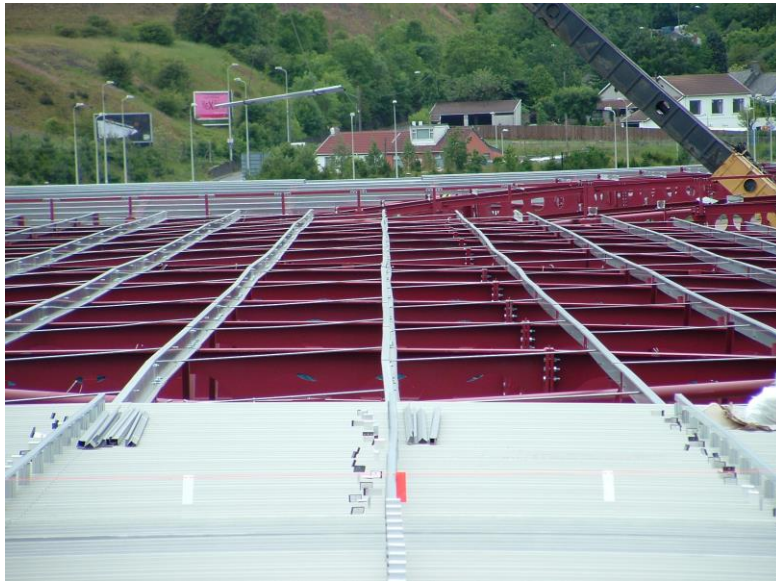


Primary steelwork installation tolerances affect secondary steelwork and then the roof sheeting unless corrected



Poor sheeting rail alignment. The wall cladding would follow the structure unless corrected

Misalignment of a purlin can be due to rotation under self-weight or loading out, deflection/sag or installation tolerances.



Misalignment of purlins as shown in this case will have an adverse effect on the installation and performance of the building envelope

If the purlin is not close to the intended position fasteners may unknowingly miss the purlins risking attachment failure and end laps could miss purlins and both air tightness and water tightness could be compromised. SCI Document P346 section 4.4 deals with erection tolerances and sections 4.4.3, 4.4.4 and 4.4.5 are most relevant.

The tolerances for x and y , downslope and vertical deviations from the intended positions are shown in figure 1 below and in the summary of span position tolerances for metal roofing in table 3 overleaf.

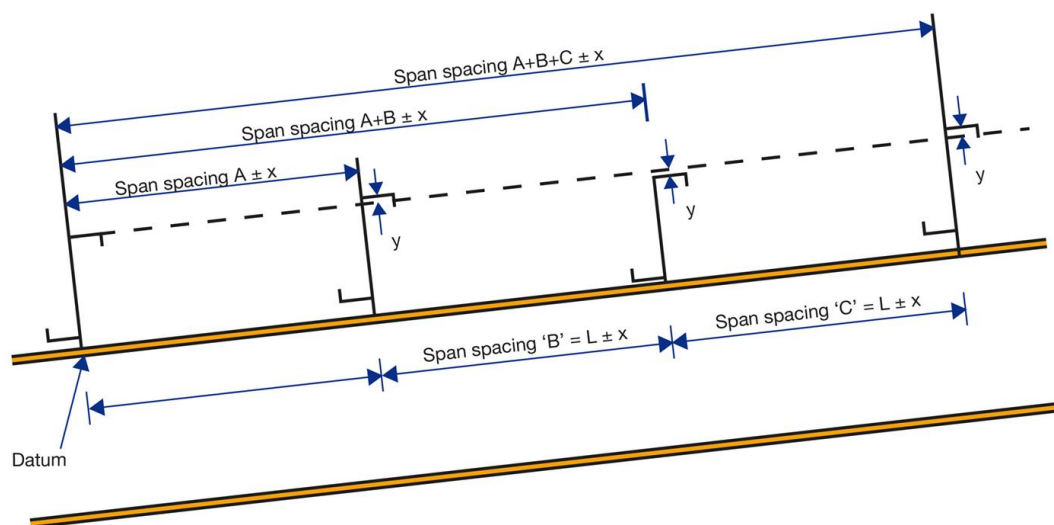


Figure 1: Limits on span position

	Built up metal twin skin system	Standing seam twin skin system	Factory insulated panels
X mm, down slope	20mm	20mm	10mm (based on a 60mm purlin flange)
Y mm, 90° to slope	Cladding manufacturer to advise	Cladding manufacturer to advise	Cladding manufacturer to advise

Table 3: Summary of SCI Document P346 span position tolerances for metal roofing

Designers, installers and main contractors need more specific guidance than this to base decisions on. The only manufacturer advice available relating to the Y value states that purlin deviation from straight line parallel to rafter/column should be L/400 for vertical cladding, L/600 for horizontal cladding and L/200 roofing (L = sheeting span).

4.2 MCRMA recommendations

MCRMA recommendations for acceptable installed deviations from the intended purlin position are shown in table 4.

	Built up metal twin skin system	Standing seam twin skin system	Factory insulated panels
X mm, down slope	20mm	20mm	10mm
Y mm, 90° to slope (L=purlin spacing, mm)	+/-L/100 (typically +/- 15mm at 1.5m purlin spacings)	+/-L/200 (typically +/- 7.5mm at 1.5m purlin spacings)	+/-L/300 (typically +/- 5.0mm at 1.5m purlin spacings)

Table 4: Purlin position tolerances for metal roofing: MCRMA recommendations

Note: Manufacturer's published guidance takes preference if different

4.3 Fastener strength

It is worth noting that the roof system is solely dependent on screw fasteners for the attachment of the roof system to the structure. The primary fasteners in this respect are generally the spacer fasteners or insulated panel fasteners.

The application of these must take into account the pull-out resistance from the actual grade and thickness of the purlins as well as fastener frequency. Fastener manufacturers should be able to provide the designer with characteristic pull-out values for the actual application.

5.0 ROOF SYSTEM END LAPS

From tables 3 and 4, it can be seen that built up systems, twin skin or standing seam, are generally accepted as being more tolerant of structure positions and deflections than factory insulated panels.

Built up systems have overlapping end laps that accommodate variations in structure location, factory insulated composite panels have butting end laps and are far less tolerant.

5.1 Single skin end lap

In built up systems, metal liner and external profiles are inherently more flexible than factory insulated composite panels. The liner and external sheets follow the structure levels, overlap at end laps and structure locations are more easily followed for applying fasteners.

This has benefits for the integrity of the fasteners and for achieving a vapour and airtight liner.

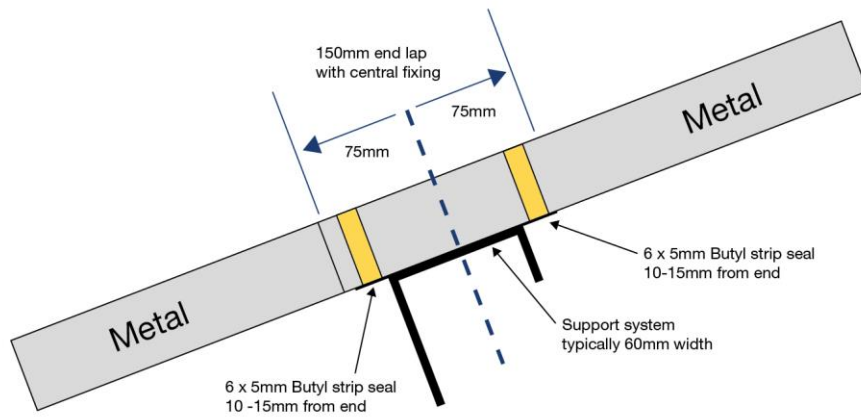


Figure 2: Typical built up system, external profile, end lap detail

5.2 Factory insulated composite panel end lap

Factory insulated composite panels are far stiffer than liner panels; end laps are butt joints - and fasteners long. Deflection of a purlin under the load of a factory insulated composite panel during installation can result in fasteners missing purlins - a reason why fly fixing (temporary fixing) is not recommended.

At a factory insulated composite panel end lap, a purlin flange is typically 60mm wide, the down slope bearing 40mm and the upslope (overlap) bearing 20mm. Bend radii can reduce the flat flange width.

The fastener has to be applied through the 40mm wide bearing. This is done with a long fastener, often to an idealised line, without being able to see the purlin. The purlin may be 10mm out of position and there could be a gap at the butt joint. The bearing to aim at could be reduced to 20mm - 30mm, and the chances of a compromised fixing increased.

In reality, the positive way to ensure that a reasonable bearing, end lap and fixing is achieved, is to use an increased flange width purlin or include an extension plate, typically a 1.6mm galvanised steel ledger angle secured to the purlin.

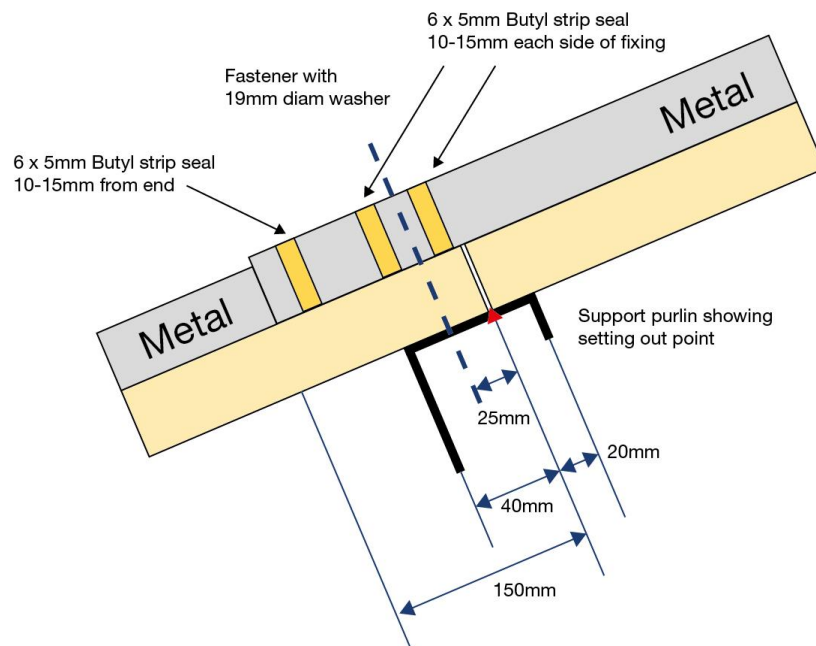


Figure 3: Typical insulated composite panel, end lap detail, no purlin extension plate

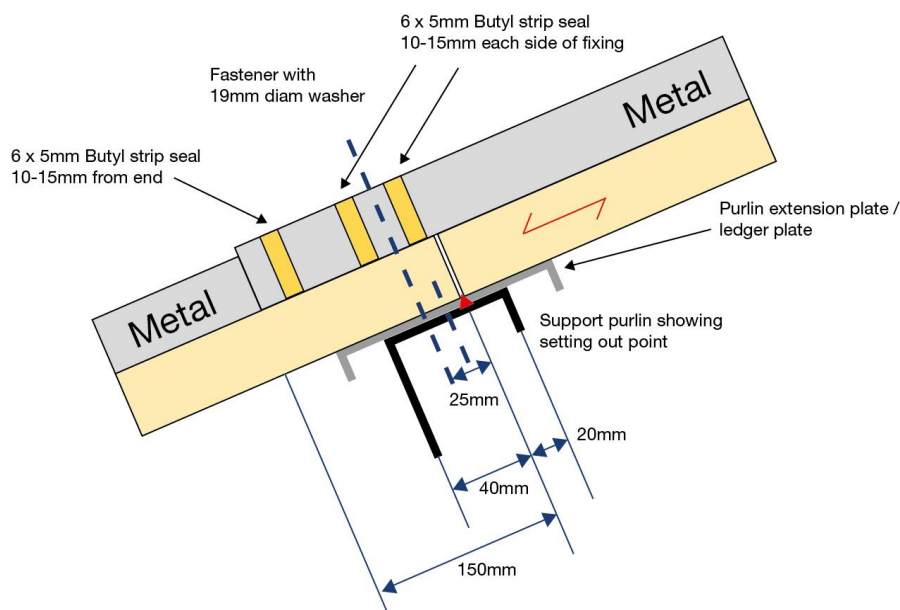


Figure 4: Typical insulated composite panel, end lap detail, with purlin extension plate

Figure 4 notes:

- i) The introduction of a purlin extension plate or ledger plate provides additional support to the end lap and allows the panel position to be adjusted at the next purlin up, to achieve 40mm panel bearing for the fastener location. The purlin extension plate is structural and must be designed and fixed to the purlin as such.
- ii) The extension plate shape shown is notional.
- iii) The extension plate increases the tolerance of the butt joint - to purlin position detail for variances due to deflection or installation tolerances and gives the installer scope for adjusting lap positions for weathertightness, non-fragility etc.

6.0 CONCLUSIONS

It is important that the deflection 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 in tables 2 and 4 and figure 4 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



This guidance document is available as an online CPD and is accredited by the CPD Certification Service. MCRMA's online CPD programme is open to anyone seeking to develop their knowledge and skills within the metal building envelope sector. Each module also offers members of professional institutions an opportunity to earn credit toward their annual CPD requirement.

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

REFERENCES

American Institute of Steel Construction Inc. AISC Serviceability Design Considerations

BS 5427:1996 *Code of practice for the use of profiled sheet for roof and wall cladding on buildings*

BS 5427 draft revision 2012 *Code of practice for the use of profiled sheet for roof and wall cladding on buildings*

BS 5950-6:1995 *Structural use of steelwork in buildings. Code of practice for design of light gauge profiled steel sheeting*

BS EN 1990:2002 *Basis of structural design*

BS EN 1991:2003 Eurocode 1. *Action on structures. General action. Snow loads.*

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

MCRMA guidance document GD 15, *Guidance for wind loadings on roof and wall cladding*

MCRMA guidance document GD 16, *Guidance for snow loading on cladding*

MCRMA guidance document GD 24, *Installation of purlins and side rails*

MCRMA technical paper No 3 *Secret Fix Roofing Design Guide*

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

Steel Construction Institute P387: *Steel Building Design: Worked Examples for Students*

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