Defence
Infrastructure
Organisation

SAFETY ALERT: Parts A, B & C

Subject: Standing Seam Roofs

Number: SA 2022-09

Standing Seam Roofs

When it takes effect: Immediately

Date of issue: 18th August 2022

DIO Sponsor: Tracy Price
Contact if different from above Sponsor: David Warr Technical Services, Engineering & Construction Defence Infrastructure Organisation. DMS Whittington, Lichfield. Staffordshire. WS14 9PY Email: insert email Address Tel: +44 (0) 7870 377774
This Safety Alert is to be read by the following so appropriate action can be taken: 1. DIO's Maintenance Management Organisations and their Supply Chains 2. DIO Regional Delivery Manager (or equivalent for non-FDIS contracts) 3. Heads of Establishments 4. Those involved in the design and procurement of buildings. 5. Airfield operators and users. 6. Others interested in the content of this Safety Alert might include: Manufacturers of Cladding and Walkways, Structural Engineers, Architects, Fire Safety Professionals, Assurance Managers, Estate Facility Managers, Assurance Managers in Regional (Service) Delivery Health & Safety Advisors, Top Level Budget Holders, Prime Contractors, Project Managers, Infrastructure Managers and Property Managers with responsibility for MOD projects and Property Management Works Services (including the legacy work of EWCs/WSMs),
Equality and Diversity Impact Assessment: This document has been Equality and Diversity Impact Assessed in accordance with the Defence Equality Analysis Guidance 2018

Document Name:	Safety Alert:
Version No:	1.12
Version Date:	16/8/22
Author:	David Warr
Reviewed by:	David Stainsby
Review Date:	18th August 2022

Document History			
Date Issued	**Version**	**Author**	**Reason for Change**

Foreword:
This 'Safety Alert' is published by Defence Infrastructure Organisation (DIO) for Mandatory application across all areas of the MoD. This standard is mandated for all contracts including USVF, overseas and PFI arrangements.

1. Aim(s)

This safety alert aims to highlight concerns relating to:

1. The specification of standing seam roofs in general.

2. Load span tables used in the design of Euroclad / Euroseam products.

3. Testing procedures for standing seam roofs.

4. Factors of safety for standing seam roofs

5. Degradation to standing seam roof connections over time and the difficulty in inspecting these connections.

6. The suitability of standing seam roofs for structures adjacent to airfields or in other high risk locations.

2. Introduction

Modern standing seam roof systems were first developed in the 1960's. They may be fitted to a variety of buildings but are widely used on large commercial and industrial buildings. Standing seam roofs may also be referred to as secret fix, concealed fix, or clip fix raised seam.

A standing seam roof is constructed of narrow metal cladding panels which may be well over 25m long and extended further using welded splices. Each panel is attached to its neighbour by a rolled seam which is formed during installation. Panels are secured to the structure below by halter clips, which are held captive within the rolled seam. The heads of the clip are a loose fit within the seam connection which allows the roof to expand and contract as temperature varies. – An example of this detail is shown in figure 1.

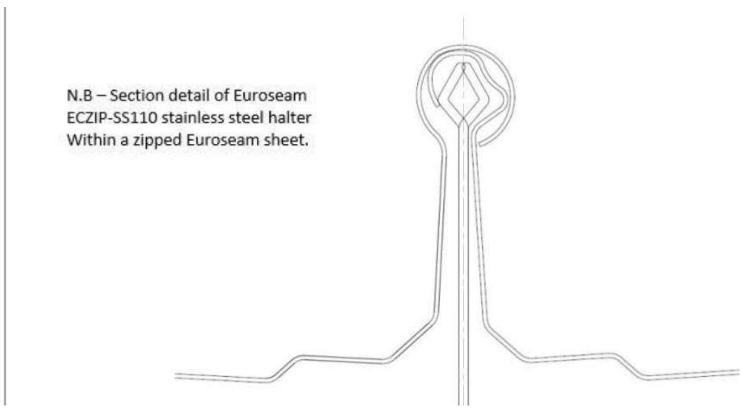

Figure 1: Halter clip and standing seam connection.

This Safety Alert details issues that have been identified whilst investigating a series of failures to a roof fitted to an aircraft hangar on the MOD estate, where large sections of cladding became detached from the roof at windspeeds substantially lower than the hangar was designed for.

These incidents represented a serious danger to both individuals and aircraft, caused significant disruption to the airfield and also resulted in closure of a public road.

The issues raised include a specific concern with Euroclad supplied load tables, which means that Euroclad supplied standing seam and secret fix roofs may potentially be under designed and at an increased risk of failure due to wind loading.

Other concerns relate to standing seam roofs in general and are not specific to the Euroclad / Euroseam product.

These concerns include:

- Factors of safety specified in accordance with BS5427 may be inadequate.
- The adequacy of design and testing procedures.
- A lack of redundancy in designs which means that failure of a single fixing may result in widespread failure of the cladding system.
- The difficulty of inspecting hidden fixings.
- The effect of deterioration of the cladding and hidden fixings and connections over time.
- The attachment of walkways, solar panels and other items to the cladding.
- The suitability of standing seam roof systems for use adjacent to airfields or in other high risk locations.
- Attention is also drawn to Cross Safety Report 811 – Galvanic (bimetallic) corrosion not considered in cladding design.

More comprehensive details can be found within Annex A of this document.

3. Background

Construction of the A400M hangar at Brize Norton was completed circa 2016. The cladding system fitted to the roof was supplied by Euroclad.

Since completion there have been issues with leaks to the roof, and 4 separate incidents where cladding has become detached from the structure due to wind loading at speeds substantially lower than the hangar was required to be designed for.

In every case the cladding system failed at the connection between the standing seam and the halter clips. This appears to be a common mode of failure for standing seam roof systems under wind loading.

The most recent of these incidents occurred in February 2022 during Storm Eunice and saw extensive damage to the roof of the hangar, with large quantities of debris scattered across the airfield and surrounding area. The area of cladding lost measured approximately 1700m^2. Flying debris included cladding, insulation, solar panels, and sections of metal over 10m across.

Video footage of this failure can be viewed at:

ukdefencejournal.org.uk/wind-blows-roof-off-of-new-hangar-at-raf-brize-norton

This Safety Alert relates to concerns that have been identified whilst investigating the failures to A400M hangar which may be relevant to other structures fitted with standing seam roofs and standing seam roofing products.

4. Part A

Assets affected by this safety alert

This safety alert affects all buildings fitted with standing seam roofs., however the primary concern relates to large buildings where the consequences of failure can be expected to be high.

There is a requirement to identify the number and location of these assets on the MOD estate.

Assets which may be at highest risk of failure

a. Buildings with standing seam cladding produced by Euroclad since 1995.

b. Recently constructed or modified buildings.

c. Buildings fitted with standing seam cladding over 15 years old.

d. Any building with known faults or defects such as leaking roofs or visible damage to cladding.

Assets of primary concern:

1) Aircraft Hangars or other large buildings adjacent to airfields or in other high risk locations (such as adjacent to railway lines or motorways), where flying debris could result in a major incident.

2) Buildings with standing seam roofs fitted with walkways which may be used as fire escapes.

3) Any other building where the consequences of failure are likely to be severe.

For older aircraft hangars on the MOD estate it should be noted that a number of these buildings have had their original roofs replaced and may still be affected.

Actions

The MMO or similar such organisation under direction from Regional Delivery (RD) or TLB shall identify any affected assets and notify the respective DIO Regional Delivery Manager.

- A list of Aircraft Hangars or other large buildings in high risk locations (or confirmation that no such assets exist,) should be provided within 3 weeks of the date that the safety alert is issued.

- Details of other buildings fitted with standing seam roofs should be provided within 10 weeks of the date that the safety alert is issued.

The DIO regional delivery Manager should notify the DIO Regional Delivery Safety Alerts Team of the Results by email for a consolidated return to DIO Technical Services. DIO-RDSafetyAlerts@mod.gov.uk

For MOD assets which are not managed by DIO or its appointed MMO's, it is requested that the TLB notifies DIO-RDSafetyAlerts@mod.gov.uk.

Details to be provided by the MMO

The details provided for each building should include:

1. Region / TLB

2. Name / reference and location of building

3. Approximate dimensions

4. Indicative usage. – e.g. aircraft hangar / warehouse / gymnasium

5. Adjacent Hazard – e.g. runway, railway, motorway, major public road.

6. Is the roof fitted with raised walkways or solar panels?

7. Do raised walkways form a fire escape route?

8. Estimated age of cladding.

9. Date of last roof inspection.

10. Any reports of leakage or other defects to the roof.

And where known:

11. Cladding manufacturer.

12. Product used.

5. Part B

Immediate actions for buildings fitted with standing seam roofs

A) Standing seam roofs may be at risk of failure under high wind conditions. Risk assessments should be undertaken for individual buildings by the responsible person(s).

B) Subject to risk assessment large buildings fitted with standing seam roofs and the immediate surrounding area may need to be evacuated during severe storms.

C) Risk assessment should also consider the safety of walkways secured to standing seam cladding which may be used as emergency escape routes.

D) Whilst the risk of failure may increase over time, for buildings which have survived recent storms, this may provide some assurance in the short term as to the windspeed that the cladding can withstand.

E) A known issue with standing seam roofs is that they are prone to creak and make noises due to movement of the cladding. – This is normal and does not indicate that the roof is about to fail.

F) In the event of high winds FOD generated by hangar roofs may necessitate closure of runways and airfields.

Users of airfields where hangars or other large buildings are fitted with standing seam roofs should ensure that appropriate contingency plans are put in place.

Inspection procedures

G) BS5427 requires that profiled sheet roofs (including those of standing seam design) are inspected at least annually, and after severe storms.

BS5427

H) DIO have contacted BSI in relation to factors of safety within BS5427 and requested clarification.

I) Issues with testing procedures and products require wider review within the industry.

6. Part C

The MMO is to notify the DIO Regional Delivery Safety Alerts Team (DIORDSafetyAlerts@mod.gov.uk), through their respective DIO Regional Delivery Manager or equivalent, of the actions completed in accordance with Part B.

7. References (The following documents provide further information)

BS5427:2016 +A1:2017 Code of practice for the use of profiled sheet for roof and wall cladding on buildings

BS5427-1:1996 Code of practice for the use of profiled sheet for roof and wall cladding on buildings

MCRMA Technical paper No 3 Secret Fix Roofing Design Guide

BSEN 1991-1-4:2006 +A1:2010 UK NA. Actions on Structures. General Actions. Wind actions

BSEN1990 2002+A1 UK NA Eurocode Basis of structural Design

BSEN16002:2018 Flexible Sheets for Waterproofing – Determination of the resistance to wind load of mechanically fastened flexible sheets for roof waterproofing

SPRA technical guidance S11b-19 Wind Loading Protocol for Calculations

Cross safety report ID 811 - Galvanic (bimetallic) corrosion not considered in cladding design

Full Scale Testing to Evaluate the Performance of Standing Seam Roofs Under Simulated Wind Loading – Habte, Mooneghi Chowdhury and Irwin.

8. Term of Reference / Abbreviations:

MMO	*Maintenance Management Organisation*

ANNEX A

Contents

A1 - Factors of Safety used in the design of standing seam roofs

A) The load span tables which Euroclad supply to designers include an overall factor of safety of 2.0 for the attachment resisting uplift. The accompanying notes state that the designer should compare the resistance values in the table to unfactored loads.

BS5427:2016 +A1:2017 *Code of practice for the use of profiled sheet for roof and wall cladding on buildings* indicates that the overall factor of safety for a secret fix attachment resisting uplift should consist of both a load factor of 1.5 for wind load and a material factor of 2.0 to give an overall factor of safety of 3.

Euroclad published load span tables omit the required load factor and are based on an overall factor of safety which is lower than the value specified by BS5427: 2016.

B) The overall factors of safety within Euroclad load span tables are understood to be determined during the process of BBA certification / testing which is understood to be conducted by an independent testing company. Other manufacturers product data sheets may also be based on incorrect factors of safety.

C) The predecessor to the code BS5472:2016 was BS5472-1:1996. The wording of the earlier version of the code is less clear than the current version and the overall factor of safety for a standing seam roof in uplift due to wind in accordance with BS5472-1:1996 could potentially be taken as either 2.0 or 2.8 depending on the reader's interpretation of sections A7 and B9.

D) Clarification as to correct factors of safety has been sought from the relevant BSI committee.

E) An overall factor of safety of 2.0 is low when comparing design standards and guidance other than BS5427 and considering the nature of a secret fix attachment.

Whilst SPRA technical guidance S11b-19 does indicates an overall factor of safety of 2 as appropriate for flat roofs subject to full scale testing, this figure assumes a reduced reliability class, and dynamic rather than static testing.

F) DIO have viewed the current load span tables for 3 different manufacturers of standing seam roofing systems.

   a. Euroclad load span tables adopt an overall factor of safety of 2.

   b. Kalzip load span tables currently adopt a factor of safety of 1.5 for wind load and 2.0 for the attachment in uplift. (an overall factor of safety of 3)

   c. Kingspan did not quote a factor of safety on the data sheet.

All of the above manufacturers specified that the values in their load span tables should be compared to unfactored characteristic loads.

A2 - Testing procedures

A) The failures to the Brize Norton hangar roof cannot be fully accounted for by the errors in factors of safety detailed in section A1., The cladding has failed twice under ten minute mean windspeeds of only 10m/s. The load at this windspeed would be expected to be approx. 8 times less than the factored load the roof was required to be designed for.

B) The exact reasons as to why failure is occurring at a much lower wind speed than expected have not been fully established, however there are concerns as to the adequacy of testing procedures used by the cladding industry to determine the capacity of the halter clip connections.

C) Testing to consider the capacity of the halter clip connections is understood to have been based on:

  a. Testing to ultimate failure based on gradual application of a uniform static pressure.

  b. Cyclic loading / Fatigue test.

D) Testing is understood to have been based on procedures defined within BS5427 and by BBA.

E) Testing of standing seam roof systems based on gradual application of uniform static pressure using airbags appears to be a common method of testing cladding systems both in the UK and other countries.

F) Testing to ultimate failure based on gradual application of static pressure does not consider the dynamic behaviour of the cladding and connections.

G) Cyclic load testing may consist of repeated gradual application of static loads at a relatively low frequency. This also fails to adequately consider the dynamic behaviour of the cladding and connections,

H) Additional concerns relating to the adequacy of testing procedures based on application of uniform load to determine capacity of standing seam roofs are raised by Habte, Mooneghi, Chowdhury and Irwin in the paper *Full Scale Testing to Evaluate the Performance of Standing Seam Metal Roofs Under Simulated Wind Loading.*

I) Because the halter clips are designed to be a loose fit within the standing seam to allow thermal expansions of the roof, there is movement within the joints. This movement may lead to dynamic effects which may increase the effective load beyond the static value or result in degradation of the connection.

- Under wind loading there may be a rapid acceleration of the sheet, followed by an impact as the slack within the joint is taken up.

- Turbulence of the wind may result in oscillation of the cladding and repeated impacts between the head of the halter clip and the standing seam and / or vibration.

J) Testing procedures to determine ultimate failure loads should consider that new components can be expected to have greater capacity than components which are worn or have been subjected to cyclic loading.

K) BS5427 section E2 requires testing by manufacturers to consider serviceability load which is defined as the load at which the fixing assembly no longer fulfils all of its design requirements..

When loads are applied to the cladding, the standing seam would be expected to undergo deformation at loads lower than the ultimate failure load.

Serviceability failure could for example:

a. Result in a tight halter clip connection which prevents movement of the cladding due to thermal effects and results in ultimate failure

b. Result in an overly loose halter clip connection which may be prone to dynamic effects and rapid wear.

If there has been any permanent deformation to the standing seam, then DIO would consider a serviceability failure to have occurred.

Typical testing procedures may not adequately check serviceability

L) Cladding that has undergone cyclic load testing has measurable residual deflection.

Test procedures for standing seam roofs, may measure global residual deflection of the cladding panels but fail to take sufficient measurements of the standing seam itself.

Measurement of the seam is required to determine whether there has been any local deformation (i.e. serviceability failure) to the standing seam.

M) Testing should consider that serviceability failures may occur at static loads which are higher than those which applied during any cyclic loading testing, but significantly lower than the load at which ultimate failure occurs.

N) Testing procedures should consider the connections at the perimeter of the roof. The test procedures defined within section E5 of BS5427 appear to be for the connections of central panels only.

O) Testing procedures should consider any possible variations in panel configuration or detail.

P) Design and testing should also consider the possibility that specified tolerances on the position of halter clips may be exceeded on site, and the implications of roof curvature on the capacity of connections.

Q) Testing to ultimate failure based solely on application of vertical loading does not account for shear loading which may be applied to the cladding.

R) Testing should consider point loads which may be applied to either the standing seam or the cladding due to fitment of ancillary components such as walkways and solar panels.

S) Samples used for testing should reflect the final product including any applied surface coating.

A3- Risk of disproportionate failure

A) Given the large number of fixings on a typical standing seam roof, the likelihood of there being a defect to a halter clip connection is high.

B) The design and testing approach specified by BS5427 is based on full scale testing and does not consider a scenario where a fixing is missing or otherwise defective., This means that all fixings are critical to the design.

C) If a single connection fails or a fixing is missing, the adjacent connections can be expected to fail in sequence, with widespread failure of the cladding system.

D) As the design of the halter clip connection allows movement. The cladding can be expected to gradually wear away at the point of contact with the halter clip, with failure becoming inevitable once the cladding reaches the end of its life.

A4 - Inspection of connections

A) The fixtures on a standing seam roof are hidden. This makes it extremely difficult if not impossible for an inspector to identify defects to the fixings and halter clip connections. – It is not possible to comply with the minimum inspection requirements specified by BS5427 section 8.1 table 16.

Figure 2: The fixings for the grey cladding are not visible to an inspector

B) Examples of defects to the connections which may remain hidden include:

c. missing or damaged screws to the base of the halter clip.

d. halter clips which are not fully engaged with the seams

e. excessive wear to the inside of the cladding at the point of contact with the halter clip.

f. corrosion to fixings or steelwork.

C) The only way to confirm items a, c and d is by unzipping the seams of the roof, removing the cladding and then reinstalling. –It is not possible to remove small sections of cladding or to open seams in the middle of a standing seam roof under tension. Checks would amount to complete removal and reinstallation of the cladding system.

D) Given that connections may be prone to degradation over time and the connections cannot be adequately inspected, older roofs may be at very high risk of failure.

A5 - Dynamic loading effects and clearance within standing seam connections

A) Calculation of wind loading for cladding systems in accordance with Eurocode En1991-1-4 is generally based on an assumption that the cladding system is sufficiently rigid and will not be prone to dynamic effects.

B) Because the connections between a standing seam roof and a halter clip are not a tight fit and are designed to allow movement, assumptions in the design process that the cladding system is rigid and does not behave in a dynamic manner may be invalid.

C) DIO are not aware of a defined standard or any accepted guidance as to the amount of movement which is permissible within a standing seam to halter clip connection and the amount of clearance is likely to vary between manufacturers and possibly individual joints. A figure of 1.5mm is understood to be typical for the Euroclad system.

D) Individual connections on site may have greater clearance than 1.5mm as the method of construction of the joint means that some variability can be expected. Increased clearance could also potentially develop over time due to wear or loads applied to the cladding.

E) For some of the failed panels on the A400M Hangar there appeared to be signs of damage and excessive wear, due to vertical oscillation of the cladding at the point of contact with the halter clip. – This wear may be caused by excessive clearance within the connection, and local turbulence of the wind.

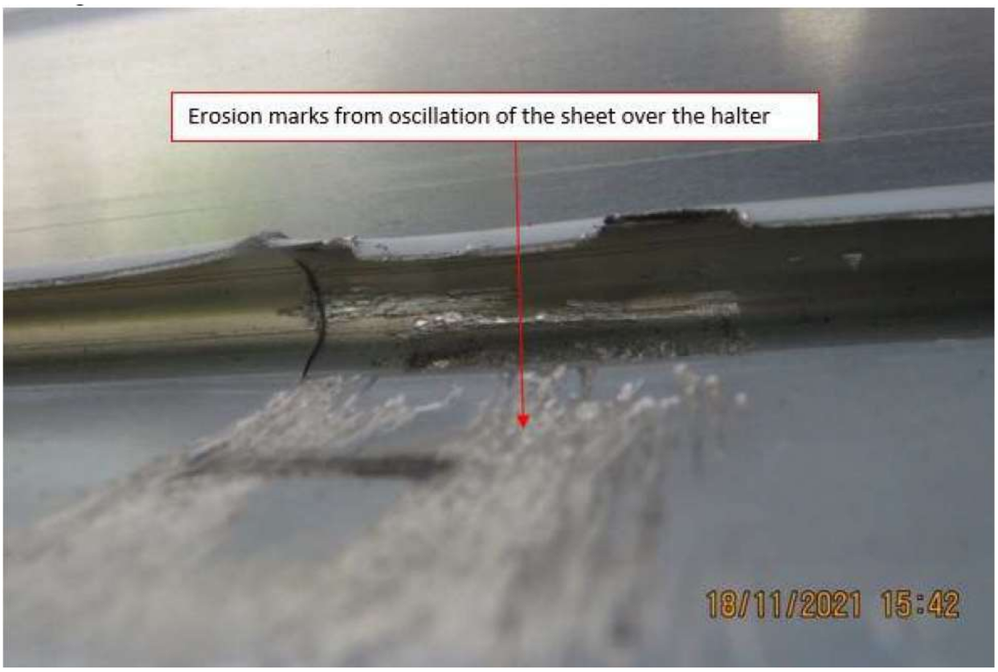

Figure 3 Scoring due to oscillation of sheet

A8 – Tolerances for halter clip installation

A) The specified horizontal tolerance on the installation of halter clips for the Euroclad system is 1mm over 3 adjacent halter clips and believed to be typical for a standing seam roof.

This tolerance is likely to be exceeded both during construction, and due to any subsequent movement within the cladding system.

A6 - Local pressure coefficients to En1991-1-4

A) Under Eurocode En1991-1-4 section 7 there are 2 different choices of pressure coefficient, Cpe1 (local) and Cpe10(overall).

Cpe1 calculates the wind pressure for areas of 1m^2 and should be used for the design of small elements and fixings.

Cpe10 calculates the wind pressures for areas of 10m^2 and is used for larger areas. – This coefficient is lower to reflect the fact that wind is not uniform, and when considering a larger area, the significance of local gusts and pressure variations is reduced.

When designing a cladding system using load span tables the designer is simultaneously required to consider a large area, and fixings. Use of CPe10 may mean that fixings are under designed, as the cladding system is unlikely to be sufficiently rigid to distribute localized loads between adjacent fixings.

B) Building designs where the geometry does not match the standard shapes specified within EN1991-1-4 may require CFD analysis or wind tunnel testing to verify pressure coefficients.

A7 - Walkways, solar panels and ancillaries fitted to standing seam roofs

A) Standing seam roofs may be fitted with accessories and equipment such as walkways and solar panels. – These items are typically connected to the cladding by attaching clamps to the standing seam and impose additional loads on the seams and halter clip connections.

B) The load span tables produced by cladding manufacturers for use by designers do not appear to consider loading from walkways, solar panels and other accessories.

C) The use of clamps could also result in localised deformation of the standing seam and affect the serviceability of the halter clip connection which secures the cladding.

D) Concerns also relate to the adequacy of the connection between the cladding and walkways or other ancillary items, which could potentially become detached from the cladding.

A8 – Galvanic (bimetallic) corrosion

A) Contact between dissimilar metals exposed to moisture may result in galvanic corrosion. Refer to Cross Safety Report 811 for further details.

Galvanic (bimetallic) corrosion not considered in cladding design | CROSS (cross-safety.org)

A9 - Suitability of standing seam roofs for structures adjacent to airfields or in other high risk applications

A) Standing seam roofs do not appear to be suitable for use in situations where the consequences of failure are high.

The integrity of these roofing systems and their ability to resist failure due to high winds is uncertain and the likelihood of failure can be expected to increase over time as the cladding wears. Critical defects can not be identified by inspection.

When the cladding does fail, the failure can be expected to be disproportionate to the initial defect with widespread damage to the cladding system, and large amounts of flying debris scattered over a wide area.